TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Umweltwissenschaften

Adaptive Capacity of Rural Communities to Climate Change in the Andes – Bolivia

Dissertation zur Erlangung des akademischem Grades
Doktor der Naturwissenschaften (Dr. rer.nat.)

Vorgelegt von
Marolyn Vidaurre de Mulczyk
Geburtsname: Marolyn Vidaurre de la Riva
M.Sc. (Ecology and Conservation)
Geboren am 13 February 1977 in La Paz - Bolivia

Gutachter:

Prof. Dr. Jürgen Pretzsch
Institut für Internationale Forst- und Holzwirtschaft, Technische Universität Dresden.

Prof. Dr. Perdita Pohle
Institut für Geographie, Friedrich-Alexander Universität Erlangen-Nürnberg.

Dr. Elizabeth Norka Jiménez Zamora
Postgraduate Program in Development Sciences, Universidad Mayor de San Andrés, La Paz – Bolivia.

Tharandt, 13.05. 2016

Declaration of conformity

I hereby confirm that this copy conforms with the original dissertation on the topic:

Adaptive Capacity of Rural Communities to Climate Change in the Andes – Bolivia

Tharandt, 13.05.2016

Marolyn Vidaurre de Mulczyk M.Sc.
Doctoral student

ACKNOWLEDGEMENTS

My first expressions of gratitude are reserved for my supervisors: to Prof. Dr. Jürgen Pretzsch, main supervisor from Technische Universität Dresden (TUD) for his support, patience and encouragement throughout the entire doctoral study. I greatly appreciate his guidance and knowledgeability; to Dr. Elizabeth Jiménez Zamora, co-supervisor from Universidad Mayor de San Andrés in Bolivia, for her contribution to the research design and guide for the assessment of social networks and valuable comments on the thesis; to Prof. Dr. Perdita Pohle, co-supervisor from the Friedrich-Alexander Universität Erlangen-Nürnberg for her willingness to give valuable comments on the thesis. Another note of gratitude goes to Dr. André Lindner, Prof. Dr. Gerald Kapp and Dr. Eckhard Auch from TUD for their openness and advice to my questions and work.

Furthermore, I wish to acknowledge with great appreciation the financial support which I received from the International Network on Climate Change - INCA Project supported and funded by DAAD (German Academic Exchange Service) and German Federal Foreign Office, the Graduate Academy and the Association of Friends and Sponsors from the TUD. Special thanks to Lic. Maria Cristina Ruiz from the Instituto de Ecología, Universidad Mayor San Andrés and Dr. André Lindner for welcoming me in this project and supporting my further enrollment in the doctoral program.

I would like to thank the Instituto de Ecología and SEMPTA for the support during my field work in Bolivia as well as the Bolivian colleagues who accompanied me on the data collection: Mr. Jan Rodriguez, Mrs. Jeanne Marie de la Riva, Lic. Nicaned de los Rios Avilez, Ms. Adela Laruta, Lic. Christian Arias. I would like to express my gratitude and deepest thanks to my colleagues at the Institute of International Forestry and Forest Products who supported and accompanied me during my stay in Dresden from the beginning. Special thanks to Maxi Domke, Elizabeth Monges, Alejandra Vovides, Francois Jost, Adefires Worku Gizaw, Asmamaw Alemu Abtew, Le Thien Duc and Francis Moyo.

Finally, a personal note, special thanks goes to my lovely husband Artur Mulczyk for his unconditional love and to my Bolivian family for the enormous motivation and constant support to complete this work. Gracias.

ABSTRACT

Climate change is one of the major contributing factors to degradation of ecological services, and these in turn are harming many people and causing poverty mainly in rural areas. The information available and the gain of knowledge on how climate change is affecting livelihood resources in the Bolivian Andes are very limited. This research aims to advance in the understanding of adaptive capacity to social and climate change in rural communities whose livelihoods are dependent upon agriculture and local resources. The proposed framework of this research focuses on the vulnerability assessment of the socio-ecological system, which targets on the identification of adaptation strategies in the context of their contribution to the overall adaptive capacity of the system. Following an exploratory design, two representative communities from different agro-ecological regions are selected as case studies: Santiago de Okola (Municipality of Puerto Carabuco, highlands) and Sita-Chorocana (Municipality of Inquisivy, inter-Andean valley). The research is conducted using a participatory rural appraisal approach and combines indicators encompassing natural, physical, human, financial, and socio-cultural variables. Data collection is based on community discussion (n=6), key informant interviews (n=31), household interviews (n=125), and local observations. Data analysis is conducted for quantitative and qualitative information. The results are presented in four main sections:

1) Integral diagnosis of the current situation in each case study considering general characteristics of the population, agriculture activities and forest resources; followed by a complete description of impacts and strategies to cope with extreme weather events and socio-economic conflicts at household level.

2) The assessment of strategies based on cultural knowledge describes the existing traditional ecological knowledge and local customs. Moreover, a mathematical model has been developed to evaluate the current knowledge needed to cope with and adapt to climate change. The outcomes point out that for the highlands the diversification of knowledge, and for the inter-Andean valley the social—pooling are strategies that contributed the most to secure crop production under extreme weather event scenario.

3) The assessment of socio-economic strategies identifies households under the category of poor as the most vulnerable group to climate change; this group is dominated by old women living alone in the communities and in charge of the farm. Based on the

redundancy analysis poverty indicators have been identified: In the highlands, off-farm activities represent a potential strategy whenever the crop production is reduced or limited; these activities are related to the labor availability in the household, health conditions and level of education. In the inter-Andean valley, out-farm and eucalyptus plantations represent a potential strategy to secure crop production when households have access to land and markets and they participate in social networks.

4) The assessment of social networks identifies the relationship between the households, stakeholders, and the municipality to cope with socio-economic conflicts and the impacts of extreme weather events. Independently of each case study, the outcomes point out the existing social networks under socio-economic scenario contributed to the implementation of a wide number of coping strategies to secure in the long-term the well-being of the household including economic development, food production, education, social organization, infrastructure, and health. The existing social networks under the extreme weather events scenarios contributed mainly to secure food production of the households by providing immediate access to labor.

This research presents evidence on how social and climate changes are the major contributing factors to increasing vulnerability of the socio-ecological system. It is the first explorative research in which cultural knowledge, socio-economic and social networks strategies are integrated to understand the adaptive capacity of rural communities in the selected case studies. The livelihood adaptation strategies identified independently of each of the two case study eco-regions showed particular characteristics related to the lifestyle, the knowledge and the socio-economic resources available in the communities; and highlights the potentialities and limitations of the households to reduce their vulnerability. Finally, the proposed model towards adaptive capacity is a tool that can be used to guide new policies and programs that target poverty reduction and minimize the adverse impacts of climate change.

KURZFASSUNG

Der Klimawandel ist eine der Hauptursachen für die Verschlechterung von Ökosystemleistungen. Dies schadet auch dem Menschen und führt besonders in ländlichen Regionen zu Armut. Verfügbare Informationen und Erkenntnisse darüber, wie der Klimawandel die Lebensgrundlage der Menschen in den Bolivianischen Anden beeinträchtigt, sind begrenzt. Diese Studie zielt darauf, die Anpassungsfähigkeit an Klimaveränderungen von Kommunen zu verstehen, deren Leben und Lebensunterhalt von Landwirtschaft und lokalen Ressourcen abhängt. Der angewandte Forschungsrahmen zielt auf die Bewertung von Schwachstellen im sozialökologischen System. Hierdurch sollen Adaptationsstrategien und ihr Beitrag zur Anpassungsfähigkeit des gesamten Systems nachgewiesen werden.

Anhand eines explorativen Forschungsdesign wurden zwei repräsentative Kommunen aus unterschiedlichen agroökologischen Regionen als Fallstudien ausgewählt: Santiago de Okola (Stadtgemeinde von Puerto Carabuco, Hochland) sowie Sita-Chorocana (Stadtgemeinde von Inquisivy, Anden-Talregion). Die Forschung konzentriert sich auf partizipative Erhebungsverfahren in der ländlichen Region und kombiniert Indikatoren, die natürliche, physische, Human-, finanzielle und soziokulturelle Variablen umfassen. Die Datenerhebung beruht auf Diskussionen in den Kommunen (n=6), Interviews mit Schlüsselpersonen (n=31), Haushaltsbefragung (n=125), sowie auf Beobachtungen vor Ort. Die Datenanalyse wurde bezüglich quantitativer und qualitativer Informationen durchgeführt. Die Ergebnisse werden in vier Hauptsektionen dargestellt:

1) Integral-Diagnose der gegenwärtigen Situation in jeder Fallstudie unter Berücksichtigung der allgemeinen Charakteristika der Bevölkerung, der landwirtschaftlichen Aktivitäten und Waldressourcen; dem folgt eine vollständige Beschreibung extremer Wetterereignisse sowie deren Auswirkungen auf Haushaltsebene und der sozioökonomischen Probleme, mit welchen die Haushalte während der Forschungszeit konfrontiert waren.
2) Die Beurteilung von Strategien, basierend auf kulturellem Wissen, legt das vorhandene traditionelle ökologische Wissen sowie lokale Bräuche dar. Darüber hinaus wurde ein mathematisches Modell entwickelt, um das vorhandene Wissen zu bewerten, das zur Anpassung an und den Umgang mit Klimaveränderungen benötigt wird. Die Ergebnisse zeigen, dass für die Hochlandregionen die Diversifizierung von Wissen und für die Inter-

Anden Valley Region das Social Pooling Strategien sind, die am stärksten zur Sicherung der Pflanzenproduktion unter dem Szenario extremer Wetterereignisse beitragen.

3) Die Bewertung von sozialökonomischen Strategien lässt erkennen, dass Haushalte, die als arm gelten, die anfälligsten für den Klimawandel sind; diese Gruppe stellen hauptsächlich alleinlebende ältere Frauen dar, die auch der Farm vorstehen. Basierend auf der Redundanz-Analyse wurden die Armutsindikatoren nachgewiesen: In den Hochlandregionen stellen nichtbäuerliche Aktivitäten immer dann eine potentielle Strategie dar, wenn die Pflanzenproduktion reduziert oder eingeschränkt ist; diese Aktivitäten hängen zusammen mit der Verfügbarkeit von Arbeitskräften im Haushalt, deren Gesundheitszustand und dem Grad der Bildung. In den Andentälern sind Aktivitäten außerhalb der bäuerlichen Wirtschaft sowie Eukalyptusplantagen eine potentielle Strategie zur Sicherung des Pflanzenanbaus, vorausgesetzt die Haushalte haben Zugang zu Land und Märkten und beteiligen sich an sozialen Netzwerken.
4) Die Einschätzung sozialer Netzwerke ist die erste explorative Analyse zum Verhalten von Haushalten unter zwei Szenarien: sozialökonomische Konflikte und extreme Wetterereignisse. Unabhängig der einzelnen Fallstudien, zeigt sich, dass, wenn es in den Haushalten sozialökonomische Konflikte gibt, sind die sozialen Netzwerke komplex und der Fokus liegt auf einer breiten Palette von Langzeitstrategien, um das allgemeine Wohlbefinden der Haushalte zu sichern. Erfahren die Haushalte extreme Wetterereignisse, richtet das soziale Netzwerk seine Aufmerksamkeit auf landwirtschaftliche Arbeitskräfte, um die Pflanzenproduktion kurzfristig zu sicheren.

Diese Forschung ist die erste explorative wissenschaftliche Arbeit, bei der kulturelle, sozioökonomische und soziale Netzwerkstrategien integriert werden, um die Anpassungskapazität von ländlichen Kommunen zu verstehen. Ferner trägt diese Forschung zur Bereitstellung von quantitativen und qualitativen Informationen bei, um Möglichkeiten und Einschränkungen zu beschreiben, die ländliche Gemeinden angesichts des Klimawandels haben. Die Anpassungsstrategien hinsichtlich des Lebensunterhalts, die unabhängig von den zwei als Fallstudien gewählten agroökologischen Regionen nachgewiesen wurden, zeigten besondere Eigenschaften bezüglich des Lebensstils und der Ressourcenverfügbarkeit in der Region. Schließlich werden durch die Modellentwicklung zur Anpassungsfähigkeit konkrete Richtlinien, unabhängig von den Fallstudien, vorgeschlagen, um politische Entscheidungsträger im Prozess der Anpassung an sich verändernde soziale und klimatische Verhältnisse zu unterstützen.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

ASITURSO	Integral Tourism Association of Santiago de Okola
CS	Cultural strategies
DI	Diversification index
DCA	Detrended correspondence analysis
EWE	Extreme weather events
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
HH	Household
INRA	Instituto nacional de Reforma Agraria
IPCC	The Intergovernmental Panel on Climate Change
LAS	Livelihood adaptation strategies
LIDEMA	Liga de defensa del medio ambiente
LPOF	La Paz on Foot
NPB	National Program of Bioculture
PDM	Plan de Desarrollo Municipal
PCI	Physical capital index
PMOT	Plan Municipal de Ordenamiento Territorial
POA	Plan Operative Annual
RDA	Redundancy Analysis
SEMPTA	Servicios Múltiples de Tecnologías Aplicadas
SENAHMI	Servicio Nacional de Hidráulica y Meteorología
SNA	Social Network Analysis
TEK	Traditional Ecological Knowledge
VMMABCC	Viceministerio de Medio Ambiente, Biodiversidad y Cambio Climático

1. INTRODUCTION

1.1 The vulnerability of rural communities to climate change

In the last decade, climate change has become a central issue for international debate, mitigation and adaptation strategies, programs and policies that have assumed an increasingly prominent place on the agenda of policymakers and practitioners all over the world, as well as in Bolivia (Lee et al. 2014). Addressing this issue at the national level has become one of the key drivers in the integral development policies (Pacheco, 2014). Currently, there have been significant advances in knowledge production at the national level related to climate change impact. Researchers point out that the unpredictability of rainfall, the rise of temperature, and the frequency and intensity of extreme weather events are the main climatic threats for the livelihoods of local people (Boillat and Berkes 2013, Jimenez 2013, Vidaurre et al. 2013, Zenteno et al. 2013, McDowell and Hess 2012, Arana et al. 2007). These threats result in rising economic losses and cause irreversible damage to the agro-ecological system (Ticehurst 2009), bringing direct consequences for overall food security, the incidence of poverty, land degradation and desertification, and increased cost for marketing and distributing food (Morton 2007, Adger and Vincent 2005).

Available information at the local level is gradually emerging. However, the vulnerability of rural communities is rising every day, making compulsory the implementation of adaptation strategies that respond to the current economic, social and market conditions. Hence, the generation of information represents an important tool to identify local strategies to mitigate vulnerability and support the building of adaptive capacity. The IPCC (2001, p.89) defined adaptive capacity as "… the degree to which adjustment in practices, processes, or structures can moderate or offset the potential for damage or take advantages of opportunities created by given change in climate". Williamson et al. (2012) report that the adaptive capacity of a certain group of people is determined by the access and ownership of a set of livelihood capitals, which originate from the complex interactions within the socio-ecological system, as is the case of rural communities in the Bolivian Andes. To understand the adaptive capacity of a socio-ecological system in the context of climate change is challenging in rural communities, where the vulnerability of the local population depends on many stress drivers (Kalaugher et al. 2013).

Bolivia covers more than one million square kilometers across a great variety of eco-systems including the Andean mountains, the Chaco desert, humid and arid valleys, and the Amazonian rainforest (Ibisch and Merida 2003). The diversity of Bolivia's ecosystems means that climate change can have various impacts in different parts of the country, and the magnitude depends on the nature of the hazard, the response from the ecosystem, and the sensitivity of the communities that rely on the local ecosystem (Ticehurst 2009, Arana et al. 2007). The government of Bolivia is addressing this problem by developing strategic actions (Matijasevic 2013). At the national level the "National Mechanism for Adaptation to Climate Change" was established in 2007. This mechanism is also supported by the National Development Plan.

Even so, each ecoregion of Bolivia needs special attention. The lowlands host 80% of the forest (FAO 2011). In this region, the main drivers of deforestation are mechanized agriculture and cattle ranching. The vision of climate change mitigation and adaptation in the lowlands is focused on the "Joint Mechanism for Mitigation and Adaptation for Integrated and Sustainable Management of Forests and Mother Earth". This mechanism is a holistic and comprehensive proposal that simultaneously advances the reduction of illegal and unplanned deforestation and forest degradation integrated with the reduction of poverty, strengthening the livelihoods of local populations, and the development of sustainable agricultural and forestry production systems, taking into account a vision of non-commodification of the environmental functions of Mother Earth (Pacheco 2014).

The other 20% of the forest is located on the eastern slope of the Andes range, in the inter-Andean valleys and, to a lesser degree, in the highlands. Here, land use change is the main driver of deforestation and forest degradation. Small-scale agriculture is responsible for deforestation on a small scale, but its contribution is still important (Müller et. al, 2014, VMMABCC 2009). Population density in this region is the highest in the country, and the main livelihood strategy is based on small-scale agriculture. Efforts on climate change adaptation in this region are focused on improving yields by significant changes in the production system (VMMABCC 2009). Yet, the government still does not have a mechanism of adaptation to guide sustainable agriculture (Matijasevic 2013).

In Bolivia, the national census shows a predominantly agricultural country, with more people working in this sector than in industry, commerce and mining as a whole (BID 2014,

Gutiérrez 2011). Therefore, the present research has a strong focus on rural communities that depend on agriculture for their livelihood. Hence, no sector has more at stake with regard to successful adaptation strategies than does agriculture (Lee et al. 2014). Over the past 10 years, the agricultural area and production have increased 50% (Ministerio de Desarrollo Rural y Tierras 2014), representing 23% of the gross domestic product (GDP), and employed about half (46%) of the official labor force. Ergo, agriculture is an extremely important livelihood strategy for rural communities in Bolivia. However, when some natural adversities or adverse weather phenomena occur, food production is greatly affected, especially for subsistence. Latest reports show that agricultural production in Bolivia has been affected by floods 43%, droughts 23%, frost 18% and hailstorm 16% (FAO 2011). Moreover, families were affected between 2009 and 2010, of which 61% received attention from local governments.

1.2 Agriculture and climate change

Direct and indirect biophysical impacts are related to climate variability and change in the agricultural sector. For example, variations of rainfall and temperature represent a direct impact on plant and animal production which results in crop and livestock losses. Indirect impacts result in soil degradation, grazing pressure, an increase of pests and diseases, loss of biodiversity, etc (Arana 2007). These impacts also affect the profitability of farming activities and income generation, leading to changes in land use, regional investment, infrastructure and the well-being of rural communities (Pearson et al. 2011, Quispe and Auguster 2011). Therefore, the need for food security and sovereignty rises (Mendelsohn and Dinar 2009).

Agriculture is one of the most climate-sensitive sectors especially in the Andean region of Bolivia, where people depend on food production for their livelihoods. The understanding of the role of climate change in agriculture is a significant challenge and depends on several factors, for example; location, scale, and the vulnerability of the people and activities concerned. Despite all the advances in knowledge generation, the impact of climate change on agriculture brings many uncertainties because agricultural production is increasingly changing and dynamic in space and time (Kalaugher et al. 2013).

Despite constraints, farmers keep trying to adapt their farming systems to the changing conditions of the environment to secure livelihoods in a sustainable way (Martin 2015). Rural

communities in Bolivia historically have developed different knowledge on production and organization to adapt to these changes. The perfect examples for that are the management of genetic resources for different scenarios of climate variability, management of soil fertility through principles of conservation and restoration of nutrients, management and control of pests and diseases and finally water resource management. These practices were possible thanks to the high level of organization, which is based on reciprocity of the social relationships and complemented by the performance of rituals (Quispe and Auguster 2011).

1.3 Problem statement

Farmers are exposed to different climatic events throughout the 12 months of the annual cycle. At the beginning of the agricultural calendar, generally farmers are exposed to intense rainfall, causing swollen rivers, floods, landslides, and water accumulation on extensive flat surfaces for agriculture production. Based on meteorological reports (SENAMHI 2010), these precipitations have undergone changes in intensity and timing cycles, discharging more water in shorter periods of time, representing damage to crops. After the rainy season, a long cold season starts earlier than expected, together with hailstorms, snow, frost, and strong wind followed by a prolonged drought season. During this season forests, pastures and crops are more sensitive to fire events. In this sense, an emergency cycle is present throughout the agricultural calendar, increasing the risk of loss of livelihoods (FAO 2011, LIDEMA 2010).

Moreover, the production strategies that have been used to dampen climate variability in rural communities in the Andean region are showing a loss due to the new market, social and economic conditions. The traditional rotation system and other ancient techniques that have been used for centuries have been lost. In addition, economic growth and migration are contributing to the loss of these techniques (Valdivia et al. 2013).

Currently, Bolivia is working for the adaptation and mitigation of climate change (FAO 2011). Nevertheless, the municipality or national resources available are not enough to cover the agricultural losses of subsistence farming. Therefore, a body of new regulations targeting risk management strategies in the agricultural production sector are rising. Yet, poor and vulnerable farmers have knowledge, attitudes and ideas about accurate risk management strategies. The consideration of this knowledge brings significant contributions to the

adaptation process because it also considers the cultural context, and it facilitates the process of adapting new strategies (FAO 2010).

The development of adequate adaptation strategies to cope with climate variability and secure livelihoods of rural communities requires a holistic knowledge of resources available (FAO 2011). Therefore, the need arises to focus attention on the vulnerability of the socio-ecological system to promote adaptive capacity in rural communities. For that reason, the present research considers as a starting point the following questions:

- What are the impacts of climate change on livelihoods in rural communities in different eco-regions?
- What is the contemporary and traditional knowledge that contributes to secure food production under a climate change scenario in different eco-regions?
- What are the socio-economic characteristics that contribute to the food production under a climate change scenario in different eco-regions?
- What is the influence of social networks in the adoption of adaptive strategies to climate change in different eco-regions?

1.4 Research objectives

This research is based on two case studies in different agro-ecoregions: the highlands and the inter-Andean valley of Bolivia. The aim is to advance in the understanding of adaptive capacity to social and climate change in rural communities whose livelihoods are dependent upon agriculture and local resources by bringing a holistic perspective on the livelihood adaptation strategies.

To achieve the objective, the following sub-objectives will be addressed:

- Diagnosis of current climatic and socio-economic threats and their impact on livelihood resources of local households.

- Assessment of cultural strategies based on contemporary and traditional ecological knowledge and its contribution to the livelihoods of rural communities.
- Assessment of socio-economic resources available in the household to cope with and adapt to climate change.
- Assessment of social networks as livelihood adaptation strategies and their contribution on the livelihood of rural communities.
- Propose a model in which livelihood adaptation strategies are integrated and support adaptive capacity in rural communities.

1.5 Scope of research

The research has been conducted to understand livelihood adaptation strategies of rural communities with a potential to support adaptive capacity. Field data has been collected for two case studies in the central Andes of Bolivia: highlands and inter-Andean valley. Research has been conducted from December 2012 to January 2015.

1.6 Structure of the dissertation

The dissertation is structured in nine main chapters. Chapter 1 introduces the research background and states the problem, outlines the research objectives, formulates research questions and determines the scope of the research.

Chapter 2 outlines the theoretical framework, cites important definitions behind the research and describes the vulnerability framework of the socio-ecological system to climate change.

Chapter 3 details the research methodologies, the selection of the case studies and the socio-economic characteristics of the selected communities, and also provides detailed information on research design, data collection, and further analysis.

Chapter 4 presents a diagnosis of the current situation in each case study considering general characteristics of the population, agriculture activities and forest resources. At the same time, a detailed description of the socio-economic situation and the impacts of extreme weather events is presented.

Chapter 5 describes and analyzes the contemporary and traditional ecological knowledge use by households, and develops an index to assess the contribution of cultural strategies in crop production.

Chapter 6 describes and analyzes socio-economic characteristic of the household and presents the diversification of economic activities as adaptation strategies.

Chapter 7 describes and analyzes social networks considering socio-economic and climatic scenarios.

Chapter 8 develops an integrated model in which cultural, socio-economic and social network strategies are integrated to identify potential adaptation strategies to reinforce adaptive capacity in rural communities.

Chapter 9 sums up the lessons learned from two case studies. Final critical reflections, limitations of the research and further recommendation for stakeholders in rural communities are also presented.

2. THEORETICAL FRAMEWORK

2.1 Co-evolution of the socio-ecological system

Rural communities in the Andes are an example of the complex socio-ecological system. The concept of a socio-ecological system considers the ecological system as biological and biophysical processes and social sub-systems as rules and institutions that mediate the human use of resources. The socio-ecological system is capable of absorbing shocks to maintain its major functions and services over time, reflecting the idea that human action and social structures are integral to nature as one system (Leauthaud et al. 2013, Adger 2006). The co-evolution of the socio-ecological system is a dynamic process of change and the integration of both sub-systems has allowed rural communities to adapt to different changes over the course of human history and will continue to do so (Nelson et al. 2010, Adger 2003), as in the case of rural Andean communities. Moreover, for the Andean people, the relationship between humans and nature is thus showing a clear notion of co-evolution between the material, social and spiritual domains of life (Rist and Dahdouh-Guebas 2006).

This concept explains the ability that communities have developed to adapt to different social and environmental stresses, for example climatic variability, understanding that climate variability is part of the wider environmental landscape of the communities. This ability to adapt is possible due to the transfer of knowledge in the culture, described as the underlying factor that provides human societies with the means and adaptation to maintain themselves in the environment (Cochrane 2006). The culture plays an important role to transfer knowledge throughout time for identifying new emerging trajectories.

2.2 The vulnerability assessment of the socio-ecological system

The proposed framework for this research focuses on the vulnerability assessment of the socio-ecological system (Macchi, 2011). This framework emerged over the past decade from an evolution of different approaches for assessing vulnerability to climate change (Reed et al. 2013, Hughes et al. 2012, Nelson et al. 2010). This approach is a consistent framework for measuring vulnerability to different stresses and comes out of mainly biophysical and social assessments which are based on the livelihood approach (Adger 2003). It attempts to estimate

potential impacts caused by climatic and socio-economic drivers that may have beneficial and/or adverse effects on the exposure, sensitivity and adaptive capacity of the communities (Engle 2011, Kallis and Norgaard 2010, Füssel 2007, Adger 2006).

Over the last few years, several authors have contributed to the literature related to frameworks for assessing vulnerability (Pearson et al. 2011). This framework is located in space and time to a particular situation and targets on the identification of adaptation strategies (Engle 2011, Pearson et al. 2011, Adger 2006). The vulnerability framework focuses on the ability of the social sub-system to cope with adverse effects on the socio-ecological system, assessing adaptation options in the context of their contribution to the overall resilience of the system, rather than in the climatic hazards and uncertainties of the natural sub-system (Kalaugher et al. 2013, Copestake 2010).

The identification of adaptation strategies based on specific context provides relevant information for policy development and the implementation of relevant actions specific to the community context. Therefore, they represent the key to promote adaptive capacity in the community (Park 2013, Pearson et al. 2011). Adaptive capacity of a rural community depending on farming refers to … "the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards" (Martin 2015, p. 53).

Based on the co-evolution model proposed by Pretzsch et al. (2014) and adapted for the local realities of Andean communities in Bolivia, this research explores the climatic hazards and uncertainties of the natural sub-system and focuses the attention on the identification of adaptation strategies on the social sub-system and its contribution to support adaptive capacity in the interface of the socio-ecological system (Figure 2.1). At the same time, the interface of the system shows the flow of socio-economic resources (material assets) and knowledge (non-material assets) throughout the existing social networks. Finally the interface of the system contributes to support the resilience of the natural sub-system and guide the development of everyday life strategies of the social sub-system.

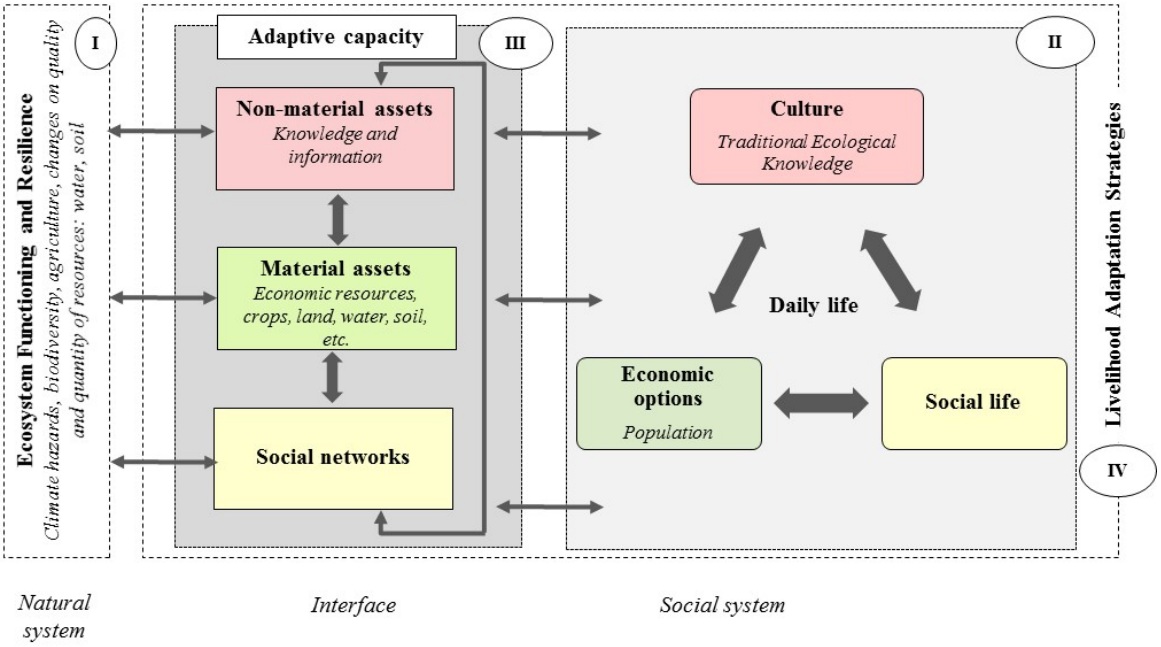


Figure 2.1: Vulnerability framework to assess the adaptive capacity of rural communities in the Andes by identifying the livelihood adaptation strategies boosted by the social sub-system adapted from the co-evolution model (Pretzsch et al. 2014).

C*omplex I* refers to the natural system, in which the function of the ecosystem is the result of numerous anthropogenic and natural interactions that are exposed to different drivers of change, threatening the provision of ecological services. The dynamic character of the natural system makes it difficult to predict the trends of climate change, its impact on biodiversity, agriculture, availability, and quality of natural resources (Pretzsch et al. 2014). Moreover, the sustainability of the system depends on the implementation of accurate policies of adaptive capacity in rural communities.

Complex II refers to the social system, in which Andean people perceive life as a continuously changing interplay of social, spiritual, and natural-material aspects. Hence, the development of a social life is guided by the cultural heritage of the traditional ecological knowledge (Delgado et al. 2010, Rist and Dahdouh-Guebas 2006). The Andean people have a holistic view integrating social, spiritual, and material aspects in the system, which are expressed in the everyday life, where the social life is rooted in unwritten traditions and cultural customs and incorporating natural, social, economic, political, and cultural components, which have an internal mechanism to that helps process outside influences (Delgado et al. 2010, Valdimir and Chirveches 2010).

Complex III focuses on the need of build adaptive capacity, which depends on the resources and assets available in the socio-ecological system that have been accumulated to achieve particular goals and objectives. These resources and assets are obtained by individuals, firms, and societies through a combination of purchasing, construction, time investment, inheritance, and redistribution (Williamson et al. 2012). The adaptive capacity also depends on the ability of an individual or group of individuals to share and exchange these resources and assets.

The resources that sustain adaptive capacity are clustered in material assets, which refers to goods and assets owned by the individual, for example, land, crop, economic resources; and non-material assets which are represented by knowledge and information (Kalaugher et al. 2013, Ensor and Berger 2009). The flow of material and non-material assets determines the social, economic and political structures that define the socio-ecological system and how individuals or groups of individuals may act in a given situation (Ensor and Berger 2009). In the context of adaptive capacity, social networks become essential to gather many of the elements of adaptation and define the access to and distribution of resources, information and knowledge (Hofstra et al. 2015, Rico García-Amado et al. 2012, Jakson 2010, Ensor and Berger 2009, Kilduff and Tsai 2005, Burt 2000).

Therefore, social networks of the system interface create linkages among social and natural sub-systems (Manson et al. 2014) and are considered drivers for adaptive capacity and resilience in the system, allowing the performance of collective actions. These actions depend on a particular web of relationship that determines power, resources, and information distribution in any situation involving multiple stakeholders (Ensor and Berger 2009). Moreover, the nature of relationships in a network will determine the household's knowledge of adaptation options and its ability to send and receive goods, services and influence across the socio-ecological system.

Complex IV refers to the livelihood adaptation strategies of rural communities in the Andes that reflect the complex customs of making decisions deeply rooted in the culture, society, and historical experience and worldviews, as well as the interaction with the physical environment. In the Andean world, daily life is the economic, social, and cultural universe that frames the lives of rural families (Baumgartner et al. 2011, Delgado et al. 2010), as explained below.

2.3 Livelihood adaptation strategies in rural communities

Rural communities in the Andes are the perfect example that illustrates the co-evolution process of a particular socio-ecological system. As mentioned above, the present situation in rural communities is the result of years of flow of knowledge and resources that defined for social behavior, management and access to natural resources, and agricultural production. For example, in the case of agriculture, the land and the knowledge to cultivate it are the legacy of past generations adapted in time by the relationship between individuals and institutions in which they reside and the resources on which they depend (Adger 2003).

This research focuses the attention on the emerging strategies related to elements that build adaptive capacity: non-material assets, material assets, and social networks. However, given the complexity of the system, the assessment of each one of these elements is conducted by identifying high-impact indicators according to the characteristics of Andean communities. 1) The selected indicators to assess non-material assets are related to Andean cosmovision where the development of daily life comes from objective material, social, and spiritual expressions of the culture (Delgado 2009). Hence, cultural strategies based on traditional ecological knowledge are selected. 2) The assessment of material assets is based on poverty indicators that explain socio-economic strategies used by households. 3) Finally, social networks represent the means by which both cultural strategies and socio-economic strategies can be shared among people in order to promote adaptive capacity. Therefore, social network strategies describe the relationship among actors and identify adaptation opportunities. The integration of cultural, socio-economic, and social network strategies identified will provide a holistic view as a starting point to propose accurate adaptation strategies with the potential to build adaptive capacity in the research areas.

2.3.1 Cultural strategies

It is well known that Andean communities were able to adapt to different environmental conditions throughout history. As proof, different agricultural technologies were developed according to the agro-ecological region. The agricultural technologies refer to the management of plant genetic resources under different contexts of climatic variability (frost, drought, hailstorm), to the management of soil fertility by principles of conservation and restoration of nutrients, to the management and control of pests and diseases, and the management of water resources. Today, the effectiveness of both productive practices and community organization are threatened by the complex processes of globalization, the market, the green revolution, simple population growth and social disintegration. As a result, the vulnerability of families that depend on agriculture for their livelihoods has increased.

In the Andes of Bolivia, the use of natural resources by rural communities has often been based on indigenous and native people's local experience related to the socioeconomic and environmental changes over long periods of time. Local responses to these changes illuminate the traditional ecological knowledge that represents the legacy of a long co-evolution between nature and human society (Ruiz-Mallén and Corbera 2013, Kallis and Norgaard 2010, Fisher et al., 2002). The traditional ecological knowledge (TEK) is defined as a cumulative body of knowledge, beliefs and practices regarding local ecosystem and management (Turner 2009). It evolves through social learning and adaptive process, and is supported by cultural transmission (Gomez-Baggethun et al. 2013, Leonard et al. 2013). Yet, the traditional ecological knowledge creation is a holistic and dynamic process that allows rural communities to respond to disturbances, based on the accommodation of new forms of knowledge and by disregarding those knowledge components that become obsolete or less useful over time (Ruiz-Mallén and Corbera, 2013).

Consequently, in rural communities where the access to new technologies is low, and where people are dependent on natural resources and rain-fed agriculture for their livelihood, the traditional ecological knowledge defines the appropriate livelihood adaptation strategies to cope with the impact of climate change. Therefore, cultural strategies are defined as the body of strategies based on the traditional ecological knowledge that allows the adaptation of the people to social and environmental changes. This knowledge is used to maintain production

level and yield in response to short-term climate variability (Lee et al. 2014). The current need to adapt to climate change may pressure communities into changing livelihoods, lifestyle or parameters of behavior, potentially changing existing notions of culture (Ensor and Berger 2009, Toledo 2002). Therefore, the cultural capital or traditional ecological knowledge has an important role to play when implementing adaptation strategies (Ensor and Berger 2009).

From the nineties, the research in Bolivia on traditional indigenous knowledge related to the management of natural resources has acquired special attention from the scientific world. Research on local technologies has started in arid zones, where the communities depend on hydric and soil resources for their livelihoods. Over time, more attention has been given to indigenous knowledge for the policies focusing on sustainable development (FAO 2011). Currently, the Plurinational State of Bolivia has recognized the role of local and ancestral knowledge as one of the key factors to guiding integrated development based on the harmony and equilibrium with "Mother Earth". This vision is reflected in the "Ley de la Madre Tierra" (Pacheco 2014) in which local and ancient knowledge are the foundation for new policies to face climate change (Gaceta Oficial 2011).

2.3.2 Socio-economic strategies

Bolivia is one of the poorest countries in Latin America and suffers from one of the worst patterns of inequality. Poverty and its effects are manifested more strongly in indigenous and native populations located mainly in the mountain area representing 65% of the population (Torrico and Mallea 2012). According to van den Berg (2010), poor people within a single country or location are often less able to cope than their richer neighbors and therefore are more vulnerable to climate change.

Moreover, climate change is one of the major contributing factors to the degradation of ecological services, and this in turn harms many people and causes poverty mainly in rural areas (Gentle and Maraseni 2012). The information available and the gain of knowledge on how climate change is affecting socio-economic resources in the Bolivian Andes are very limited. Recent research in Bolivia points out the high uncertainties for local communities due to the limited amount of systematic information and low-resolution climate scenarios. The

increasing occurrence of extreme weather events results in increasing economic losses and causes irreversible damages to the agro-ecological system (Ticehurst 2009).

Finally, there is evidence that climate change tends to be more severe when people rely on weather-dependent rain-fed agriculture for their livelihood (Gentle and Maraseni 2012), because this bears direct consequences for overall food security (Morton 2007). For example: reduction of the food production, decrease in crop varieties that can be grown, and the spread of pests result in lower yield from agricultural production. In addition, climate change is also responsible for the loss of livestock, an increase of land degradation and desertification, increased cost for marketing and distributing food, etc. (Adger and Vincent 2005, Morton 2007). Moreover, as expressed by Williamson et al. (2012), local economies will also be impacted by climate change and the response of economies and their inherent capacity to adapt will have a significant effect on the overall adaptive capacity of integrated social and economic systems.

2.3.3 Social network strategies

Social organization is considered a basis for livelihood adaptation strategies because of its contribution to the overall adaptive capacity of the socio-ecological system. More precisely, it contributes to take steps toward changing and implementing policies and programs that will lead to successful adaptation (Hughes et al. 2012). The assessment of social organization identified relations and practices developed in the communities that contribute to climate change adaptation (Eriksen and Selboe 2012).

In rural communities, the social organization is structured according to the agricultural activities and other economic activities linked to seasonal variations throughout the year. Therefore, farmers develop different economic activities depending also on the climatic variability. These economic activities follow a traditional social organization. Further on, farmers in rural communities depend on the interaction with other farmers and stakeholders in order to succeed in agricultural production. These interactions are guided by the unwritten rules (communitarian principles) of the social organization. The Andean indigenous social and cultural organization found its articulation principally in the family and community

organization. The assessment of social organizations can be done by analyzing the practices and social networks carried out by community members and stakeholders.

The social networks in rural communities secure the food production and represent a potential adaptation strategy to climate change. A network centers its attention on the relationship between a set of individuals, and the connections that link diverse individuals and institutions, either directly or via other actors, responding to the needs of a particular household group or groups (Ensor and Berger 2009). Social capital is defined as the features of social organization, such as trust, norms, and networks that can improve the efficiency of society by facilitation coordinated actions (Agurt 2014, Righi 2013). Moreover, in the context of climate change, social capital is an important determinant of the people's well-being and plays an important role obtaining and providing access to resources and information for individuals or societies (Adger 2003). The social capital theory provides an explanation for how individuals use their relationships to other actors in societies for their own and for the collective good (Adger 2003).

3. RESEARCH METHODOLOGY

3.1 Case study design

Following an exploratory design, the research has been carried out based on a case study approach. Two eco-regions in Bolivia were selected as case study areas: highlands and inter-Andean valley. The general context of each case study is evaluated independently and a set of analysis is conducted to investigate contemporary lifestyle phenomena in the selected areas (Yin 2009). The criteria proposed for the selection of the case studies were the following: 1) traditional farming communities, 2) communities located in different agro-ecological regions and 3) communities depending on natural resources for their livelihoods. The assessment of the case study in the highlands is based on the community of Santiago de Okola and the case study in the inter-Andean valley is based on the communities of Sita and Chorocona.

3.2 Selection of the case study area

Three communities of the Aymara indigenous nation were selected: Santiago de Okola, Sita, and Chorocona (Figure 3.1). Moreover, these communities are located in Municipalities with the highest poverty index (PNB 2011). The first community, Santiago de Okola, is situated in the highlands (4000 m. asl.), on the northwest slopes of the Real Mountain Range and is bordered to the west by the Titicaca Lake. Land use is dominated by agriculture (roots and tubers), livestock, mining, and tourism. The second and the third communities, Sita and Chorocona, are neighbors situated in the inter-Andean valley (3200 m. asl.) on the eastern slopes of the *Kimsa Krus* Mountain Range (Inquisivy Municipality). Here, land use is dominated by mountain forest, forest plantations (*Eucalyptus sp*.) and agriculture (horticulture and fruit growing).

3.2.1 Santiago de Okola - Highlands

Santiago de Okola is located 145 km NE from La Paz city (15 51’ 55.1’’ LS and 68 00’ 04.4’’ LW), within the limits of the Municipality of Puerto Carabuco (from now on referred as highlands, Figure 3.2). In this area, the original vegetation has undergone a transformation from its natural state through intense human occupation and the history of land use (Hanselman et al. 2011).

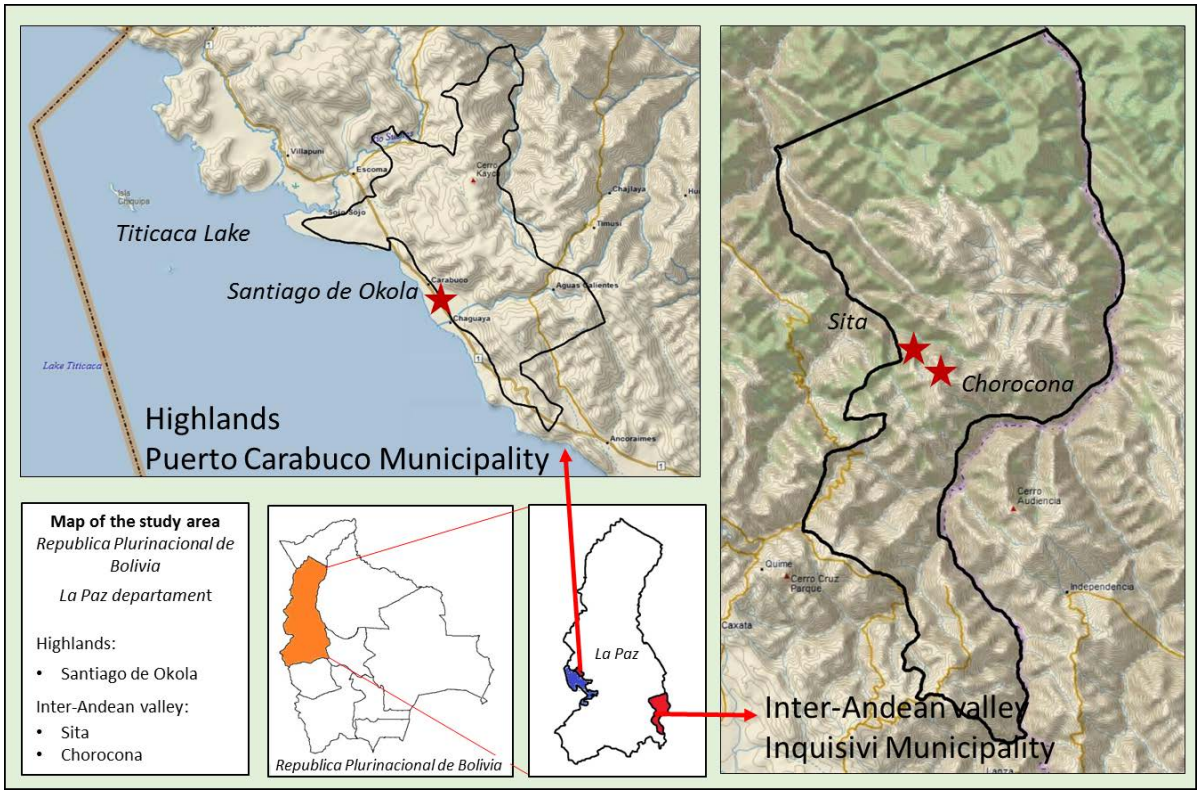


Figure 3.1: Map of the study area.

The vegetation is dominated by grasslands with shrubs, low grass in moist places and thickets of resinous shrubs. Forest resources are reduced, nevertheless, native trees can be found in the area in small and isolated patches. Today the landscape is dominated by crops, and natural ecosystems are no longer present. Therefore, the conservation status of this area is critical (Ibish and Merida 2004).

Santiago de Okola is a small, traditional fishing and farming village. About 80 families live in the community, of which some families live year-round and others live part-time in the community and part-time in La Paz and El Alto. The development of culture in the settlement of human population throughout time has allowed the domestication of a significant number of varieties of tuber and root crops. Currently, Santiago de Okola has gained recognition as a cultural and tourist center by the Municipality of Puerto Carabuco (Proimpa 2009). In the agricultural calendar 2008-2009, 17 species and 109 cultivated varieties were recorded (Proimpa 2009). Farmers from the community are well known for the conservation of traditional knowledge on the use and management of agrobiodiversity. The principal crop is potato as it brings significant economic resources and it can be traded in local markets or in the city. The diversity of *oka, isano* and *papaliza* is reduced, and use mainly for consumption.

Figure 3.2: Panoramic view of Santiago de Okola community: Highlands - case study.

The climate within the Puerto Carabuco Municipality is that of a high mountain region with a tropical hydrological regime of great inter-annual irregularity. In the surrounding area, the presence of the Lake Titicaca exercises a moderating influence on temperatures and rainfall (Jimenez 2013). There are great seasonal variations as, the area has wet summers and dry winters, with a rainy period from December through March and a dry period from May through August (Figure 3.3). The air temperature varies within the system depending on latitude, longitude, altitude and proximity to the lake, with minimums of -10 to -7°C and maximums of 19 to 23°C. Humidity is low throughout the system, with an average of 54 percent and variations depending on latitude and season (SENAMHI 2012).

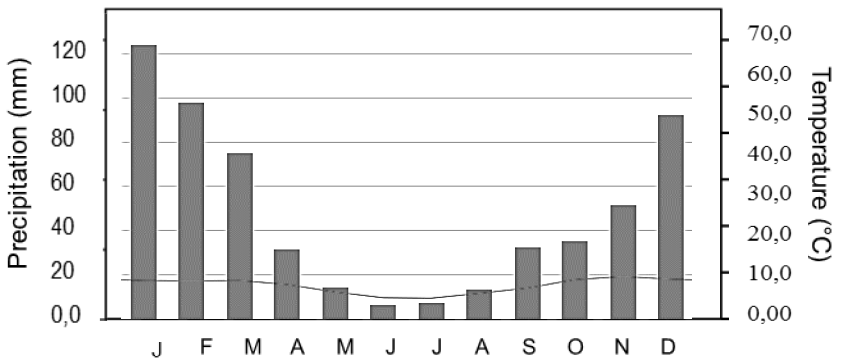


Figure 3.3: Mean monthly rainfall and temperature of Puerto Carabuco Municipality (SENAMHI – database 1991 – 2012).

3.2.2 Sita and Chorocona – Inter-Andean valley

The case study of inter-Andean valley is represented by the communities of Sita and Chorocona, located within the limits of the Central District of Inquisivi Municipality, which belongs to the first section of the Inquisivi Province, in the South West of La Paz department, Bolivia (66º43'29.49''and 67º17'58. 62'' WL; 15º47'34.9'' and 17º18'20.46'' SL,). About 150 families live in both communities, of which most families live year-round and others live part-time in the community and part-time in Quime and Inquisivi, the major population centers of the region. Sita and Chorocona communities (from now on referred as inter-Andean valley) shared physical, biological and socioeconomic characteristics. The territory present moderate inclination, soil with laminar water erosion and furrow erosion. A Greater percentage of their territory is covered by native vegetation (Figure 3.4). Further on, the access of water resources comes from the same source. Road connections and transportation facilities with other communities and population centers are the same. Both communities depend on the agricultural production for their livelihood, but mainly on the peach production. Local and regional regulations are planned from the Municipality based on the traditional customs of the communities region.

Figure 3.4: Panoramic view of Sita and Chorocona communities, inter-Andean case study. Photo by: Omar Torrico

The municipality is characterized by mountain landscapes shaped by glacial processes, deep valleys as a result of fluvial erosion processes (PMOT 2011). The valleys (2700-3200 m. asl.) are in the form of alluvial terraces and beaches surrounding the rivers flowing through the

region from west to east, with slopes between 2-70%. Land use is designated to agriculture, forestry and/or livestock, and the most important products are fruits (peach, plum, apple) and vegetables (beans, peas, onion, corn), which are intensively cultivated. The access to land depends on the location and accessibility of productive activities, rural roads and trails (Bioandes 2009). It was observed that agriculture was extensive and located in different ecological zones, with a high concentration on mountainsides with different slopes, influenced by the orientation of the sun, while a smaller number of the farms was found in flat areas.

According to local reports from the municipality (PMOT 2011, NPB 2011, PDM 2011), the Inquisivi central district, has suffered a great loss of its natural forest, especially of *Polylepys spp.* and *Buddleja spp.* (3500-4000 m). During the fieldwork, the use of firewood extracted by the local communities was observed. At the same time, as reported in PDM (2011) vast areas of the forest have been impacted by shifting for agriculture and forestry purposes, showing patches of bare land or succession. In this zone exist extensive areas of eucalyptus plantations. Moreover, the municipality of Inquisivi presents a variety of ecological zones under different climatic conditions and at different altitude ranges. Thus, the climate condition in this municipality is conditioned by the geographical context of the area. In general, January is the month with the highest rainfall with an average of 229.4 mm, and June is the lowest with an average of 32.6 mm (SENHAMI 2012). Further on, the thermal behavior of the area is described as a semi-arid and sub-humid zone, characterized by temperate and dry temperatures, reaching a maximum of 26.4°C in November and 9.2°C in July (Figure 3.5). According to this data, two seasons are distinguished, rainy season and dry season.

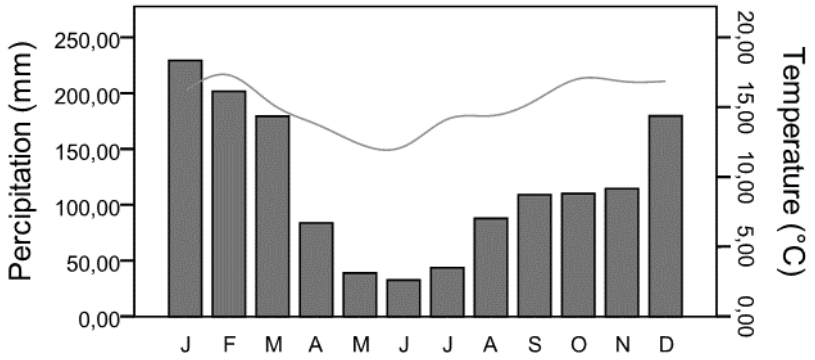


Figure 3.5: Mean monthly rainfall and temperature of Inquisivi Municipality (SENAMHI – database 1975 – 2011).

3.3 Data collection

Data collection for the case studies has been carried out using tools developed for the participatory rural appraisal approach to gain a broad understanding of the socio-environmental system at the community level. The tools applied were: local observations and literature review, workshops, and key informant interviews. Moreover, the case study was complemented by a household survey in order to collect qualitative and quantitative data regarding the current situation of the households using semi-structured interviews.

Data has gathered from multiple sources at various time points during three main fieldwork stages: December 2012 to March 2013; October to November 2013 and November 2014 to January 2015 (Figure 3.6). The first stage of fieldwork is focused on the presentation of the research to local authorities and households in both study areas for authorization to implement the research. Every year preliminary outcomes have been presented to the communities. At the end of the fieldwork, the information is returned to the communities and local authorities.

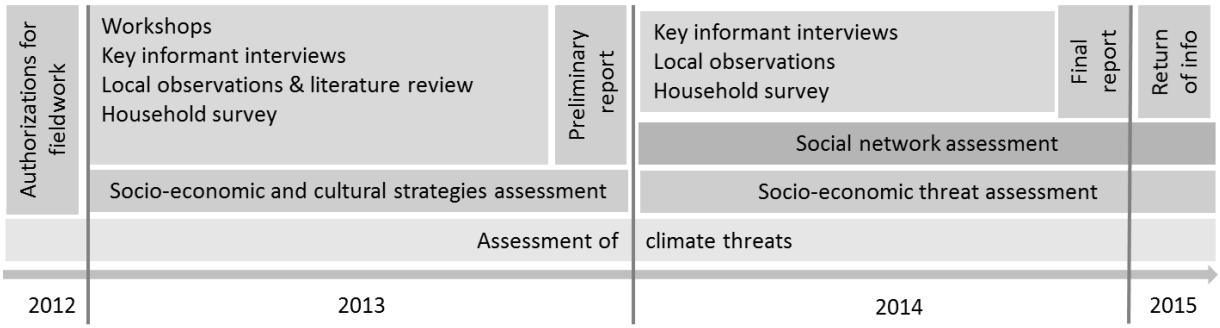


Figure 3.6: Timeframe for the implementation of fieldwork from 2012 to 2015.

3.3.1 Local observation and literature review

Partial information was collected and systematized from the literature review. The main sources of information were: climatic data from the meteorological stations Quime, Chorocona, Puerto Carabuco and Puerto Acosta (SENAMHI 2012), census data (INE 2013), municipality reports from "*Plan de Desarrollo Municipal*" – Municipality development plan (PDM Puerto Carabuco 2011), reports from institutions (PROIMPA 2008), and scientific publications. Furthermore, direct observations have been carried out during the fieldwork to observe current practices in the communities. It helped to capture data about land and natural resources used by households, informal and formal rules, spiritual places, and markets for

agriculture. As a rule, data from direct observation were used to cross-check the data gained from interviews.

3.3.2 Workshops

The objective of the workshops was to open community discussions to include the participation of local authorities and members of the communities in the research. The participation of women and young community members has been encouraged. A total of six workshops were implemented: two in the highlands (December 2012 and November 2014) with an average participation of 52 community members per workshop, and four workshops in the valley with an average participation of 25 community members per workshop (Figure 3.7). During the process, preliminarily outcomes from the household survey have been presented and validated. The principal methodological tools applied were open discussions and a vulnerability matrix.

Figure 3.7: Workshop with households and local authorities in the inter-Andean valley.

A vulnerability matrix has been used to determine the level of impact of the climatic threats on livelihood resources and to determine which livelihood resources are most vulnerable. This tool also contributes to identifying coping strategies currently used to address impacts (Table 3.1). The filling of the matrix begins with an open list of resources available in the community, all resources named by participants are noted in the left column of the table and all the threats are noted in the first row of the table. Once both lists were completed, the participants determined through a consensual process the impact degree that each threat has

on each resource by using the categories 0 to 5, where 0 is null impact and 5 is the extreme impact on the resource (Macchi, 2011).

Table 3.1: Template for the vulnerability matrix.

Threats / Resources	Threat 1	Threat 2	Threat 3	Threat 4	Threat 5	Total
Resource 1						
Resource 2						
Resource 3						
Resource 4						
Total						

Research own derivation

Additional questions were asked during the elaboration of the matrix in order to complement needed information for subsequent analysis on adaptation strategies:

- Is it an actual strategy used to cope with threats?
- Is it working?
- Is there any other strategy that you would like to use to reduce the impact of threat over your resources?
- What kind of resources do you have that can help you to adopt new strategies?
- And, what limitations do you have to adopt new strategies?

3.3.3 Key informant interviews

The objective of the key informant interviews was to identify the current social and climate situation that threaten the lifestyle of the families living in the communities. Additionally, these interviews helped to collect information related to social networks in both case studies. Therefore, face-to-face open interviews were applied at the municipality and community level focusing the criteria (Table 3.2; Appendix 1):

- Municipality: public officers from the municipality with direct interaction in the communities selected (e.g. Agriculture department, Forestry department, Environmental department).

- Community: local leaders of the existing social organizations (syndicates, federations and associations); community leaders (first and second authority leaders) and directors of the non-governmental organizations identified.

Table 3.2: Participation of stakeholders in the development of key informant interviews for two case studies.

Case study	Key informant interviews			Total
	Municipality	**NGO**	**Community level**	
Inter-Andean Valley	**3 interviews:** • Sub-mayor • Department of agriculture (leader) • Department of agriculture (assistant)	**2 interviews:** • LIDEMA • SEMPTA	**13 interviews:** • Community leader • Sub-community leaders (water, education, irrigation) • Peach producers association • Bartolina Sisa Union • Agrarian center association	18 key informants interviewed
Highlands	**2 interviews:** • Municipality representative • Department of agrarian development	**2 interviews:** • La Paz on Foot • PROIMPA	**9 interviews:** • Community leader • Sub-community leaders (water, education, land, irrigation) • Fishermen association • ASITURSO	13 key informants interviewed

Own research derivation

3.3.4 Household survey

The general objective of the survey was to identify the current situation of the households, and more precisely to identify the livelihood adaptation strategies implemented at the household level. Extensive interviews were conducted in 2013 and 2014 with 125 households; 61 households from the highlands and 64 households from the inter-Andean valley. About

30% of the population has participated in the survey and more than 80% of the households have participated in both years of research. (Table 3.3).

Table 3.3: Sample size of household interviews

Case study	Nr. Interviews 2013	Nr. Interviews 2014	Total households interviewed
Highlands	39 (48%)	37 (46%)	61
inter-Andean valley	44 (29.33 %)	45 (30%)	64
Total households interviewed	83	82	125

Research own derivation based on sample size

The households were selected randomly from different sectors within the communities in order to have a heterogeneous sample group that shows the diversity of household conditions. The selection of households in the research was based on the acceptance and mutual agreement with the head of the household and local authorities. In answering the questionnaire, the head of the household was considered to be the person able to provide relatively accurate data.

The questionnaire developed for this interview was based on the Sustainable Livelihood Approach (Tang et al. 2013). The household interview considered open questions (qualitative) and semi and structured questions (qualitative) and was structured in four sections: 1) climate and socio-economic threats, 2) cultural strategy assessment, 3), socio-economic strategy assessment and 4) social network strategy assessment (full interview in Appendix 2).

3.4 Variables and measures of variables

Based on the theoretical framework developed for the research in section 2.2, key variables and measures are grouped into four main stages: 1) Integral diagnosis, 2) Cultural strategies, 3) Socio-economic strategies, and 4) Social network strategies (Table 3.4).

Table 3.4: Variables and measures of variables.

Research stage	Variables	Measures	Data collection tools
Integral diagnosis	• Livelihood resources at community and household level	Descriptive analysis of current situation in the case study: • Population • Agriculture • Forest resources • Socio-economic conflicts • Extreme weather events	• Local observation & literature review • Workshops • Key informant interviews • Household survey
Cultural strategies	• Traditional ecological knowledge • Contemporary knowledge	• Descriptive analysis of existing knowledge to cope with socio-economic and climatic threats • Development of an index to assess of cultural strategies	• Household survey • Workshops
Socio-economic strategies	• Livelihood resources • Economic activities	• Ranking of wealth groups • Index of economic diversification	• Household survey • Workshops
Social network strategies	• S.N. Structure • S.N. Function	• Social network as coping strategies to face socio-economic and climatic threats.	• Key informant interviews • Household survey • Local observations

Research own derivation

3.4.1 Integral diagnosis

Livelihoods characteristic of the household

This section was designed to capture socio-economic aspects at the household level. The information collected included qualitative and quantitative data regarding natural, physical, financial, human and social resources (Table 3.5). The variables measured included characteristics of the household head (name, age, gender, formal education) and the structure of the family (number of kids, labor availability, migration patterns, health), land use patterns,

use of/access to agricultural inputs, livestock systems, market, income sources and economic activities (Ansoms and McKay 2010; van den Berg 2010).

Table 3.5: Variables measured to assess livelihood portfolios at the household level.

Indicator	Variables measured (unit)
Natural capital	• Number of crops and varieties used (number) • Livestock (number, variety)
Physical capital	• Land (number of hectares owned by the household) • Cultivated land (number of hectares currently used for cropping) • Irrigation system (number of hectares with access to irrigation) • Crop distribution (number of areas where the cultivated plots are placed; each area has unique characteristics of slope, exposure, and elevation inside the community limits) • Shelter, access to water, assets and goods
Human capital	• Labor (number of adults with the ability to work in the household) • Education (number of years of formal education) • Health conditions (number of household members with health problems during the research) • Migration (number of relatives outside the community) • Gender (percentage of female household heads) • Age (household heads) • Language (number of languages spoken by the household head)
Financial capital	• Investment in modern technologies, tractors (USD) • Income (crop production, livestock production, natural-resources-related activities, out-farm activities, off-farm activities, remittance, and others (see more detail on Table 3.7) • Access to markets (distance in minutes to the market and number of markets visited)
Social capital	• Household size • Social networks (number of interactions with members of the community and outside the community) • Access to health insurance • Access to bank credit

Selected variables based on: Gentle and Maraseni 2012, Soltani et al. 2012, Macchi 2011, Ansoms and McKay 2010, Daze et al. 2009, Wiggins 2009.

Climatic and socio-economic threats for the case study

Based on Macchi (2011) and the methodology proposed by *Liga de Defensa del Medio Ambiente* (2010), the research describes the current situation of the households in the selected

case studies. The diagnosis focusses the attention on the identification of climatic and socio-economic conditions that represent a threat to the well-being of the household, followed by the identification of livelihood resources affected by these threats.

The identification of climate threats comprises the number of households affected by extreme weather events during the research period and the number of household resources affected by the occurrence of these events. The occurrence of extreme weather events has been identified by asking the households if they have experienced damages on their livelihood resources direct relate to these events. The impact was evaluated from 0 (no impact) to 5 (high impact), based on the number of resources affected after the occurrence of the extreme weather event. A descriptive analysis based on number of households' replies was used to determine the intensity and seasonality of extreme weather events during the research period. Additionally, the percentage of households affected by these events and the percentage of damage on livelihood resources were calculated.

The identification of socio-economic threats comprises problems at household level related to: 1) economic resources (income, source of employment, labor), 2) human capital of the household (age, health, education), 3) access to basic services (water, electricity) and 4) market-oriented problems and agricultural production in general (access to market, market prices, pest attract, access to technology, loss of agro-biodiversity and livestock). Based on the number of household responses, a descriptive analysis was carried out to calculate the percentage of households affected by socio-economic problems or conflicts.

3.4.2 Cultural strategy assessment

The assessment of cultural strategies comprises two sections. The first one describes traditional and contemporary knowledge use by households to cope with climatic and socio-economic threats identified in the previous stage. The second section focuses the attention on the development of an index to measure the influence of cultural strategies on the livelihoods of households.

Based on Wang et al. (2013), 35 livelihood adaptation strategies have been identified and were grouped into seven major categories: cultural identity, weather forecasting, mobility, storage, selection of agricultural practices, social-pooling, and diversification of economic

activities (Table 3.6). These categories represent the use of traditional ecological knowledge and the incorporation of new technologies and contemporary knowledge as livelihood adaptation strategies. 1) Cultural identity integrates variables that defined the Aymara customs and traditions. 2) Weather forecasting identifies local knowledge related to the observation of the natural phenomenon that guides agricultural production. 3) Mobility refers to the ability to access resources from other regions; access to market, barter-trade practice and migration. 4) Storage food practices and transformation based on traditional ecological knowledge. 5) Selection of agricultural practices knowledge refers to local strategies use by households to secure agricultural production. 6) social-pooling, comes from the definition "an adaptation practice that involves joined ownership of assets and resources; sharing of wealth, labor, or income from particular activity across households; and /or mobilization and use of resources that are stored collectively during times of scarcity" (Rodima-Taylor 2012, 131p.). 7) Economic diversification integrates skills and knowledge of the households to developed different activities.

Table 3.6: Categorization of cultural strategies based on traditional ecological knowledge and identification of variables for its measurement.

Categories	**Sub-categories (variables measured in percentage of households)**
Cultural identity	• Performance of rituals and ceremonies related to agriculture production (%) • Transfer knowledge from elders to young generation (%) • Customs and traditions of the communities (answers were ranked from 0 = nothing to 5 = high belief and practice).
Weather forecasting	• Use of zoological indicators, phyto-indicators, astronomic and atmospheric indicators to understand or predict the weather (answers were ranked from 0 = nothing, to 5 = high belief and use of this knowledge).
Mobility	• Access and availability of land in different ecosystems (# of areas) • Barter-trade practices in the community (%) • Barter-trade practices with other regions (%)

	• Migration (%) • Access to local markets (% and distance) • Access to regional markets (% and distance)
Economic diversification	• Diversification of income sources: crop production, livelihood production, out-farm activities, wage work, remittances (and bonds) and others (Table 3.7).
Storage	• Water storage (%) • Food storage (%) • Food storage for livestock (%) • Food processing and transformation (%)
Social-pooling(*)	• Participation in *minka* activities (%) • Participation in *ayni* activities (%) • Involved in local associations (%) • Involved in local federations (%) • Participation as community leader (%) • Involved in programs or projects from the government (%) • Involved in programs or projects from non-governmental organization (%)
Selection of agricultural practices	• Selection of species and varieties adapted to local environment (%) • Seed selection (%) • Access to irrigation system (%) • Access to modern technology (tractors) (%) • Use of firecrackers to prevent hailstorms (%) • Changes in the agricultural calendar (%) • Reduction of working hours (%) • Dig water channels (%) • Use of fertilizers (%) • Crop rotation techniques (%)

Based on Wang et al. 2013 where social-pooling (*) refers to the number of interactions that households have with other community members, relatives, and stakeholders in the community.

Two sets of analysis were undertaken: (1) calculation of the value of every category of cultural strategies (CS-category), and (2) statistical comparison of CS-category between the two regions. Four steps were taken to analyze the value of CS. The first one was to calculate raw data into appropriate measurement units, such as percentages, ratios, distance, time, etc. Second was the standardization of variables. As they were measured on different scales, this standardization was done in order to combine all measures in a single CS index, following a simple arithmetic formula to calculate the quotient of the difference between the actual score and the minimum value obtained from the total sample (i.e. both regions) and the difference between the maximum and minimum values from the total sample. Third, every CS-category was valued by the sum of the standardized value of each variable divided by the number of variables in each CS-category. For example, CS-storage is calculated by summing up the standardized value of food processing, plus food storage, plus food storage techniques, all divided by 3 (number of variables). Finally, for the statistical analysis, a tree regression analysis is used to determine which of the CS-categories influence crop production in these regions. Here, the value of crop production represents the income of the household due to the agriculture production (see section 3.4.3; Table 3.7)

3.4.3 Socio-economic strategy assessment

The assessment of socio-economic strategies contemplates two main analysis: the household wealth categories and the economic diversification:

Household wealth categories

An ex-post analysis of wealth ranking or "well-being" was used to determine the economic attributes of households for each case study. This analysis shows information on the relative well-being of households, and it enables the determination of the social and economic status of households. Furthermore, the information generated by the wealth ranking helps identify the poor households in the communities. This classification was defined by using a hierarchical cluster analysis based on the criteria of ownership of the land (hectares), income, physical capital index, education and age of the head of household, as detailed bellow:

- ***Income***: is the difference between total income from all economic activities minus total expenses or household economic investments, divided by the number of household members with the ability to work.

- ***Physical capital index (PCI)***: The calculation of the index was modified from Ansoms and McKay (2010) following the criteria: availability of transportation: 0 = public, 1 = motorbike, 2 = car; availability of rooms per adult: 0 = less than 0.5 rooms/adult, 1 = 0.5 - 1 room per adult, 2 = over 1 room per adult; quality of walls: 0 = adobe; 1 = adobe + brick, 2 = brick; quality of roof: 0 = straw, 1 = straw + calamine, 2 = calamine; quality of sanitation: 0 = none, 1 = open pit latrine, 2 = flushing toilet; quality of energy for cooking: 0 = firewood, 1 = firewood + gas, 2 = gas. Using the formula:

  PCI = (availability of transportation + availability of rooms per adult + quality of walls + quality of roof + quality of sanitation + quality of energy for cooking) / 6

- ***Education***: Number of years the household head attended school.

Complementary variables such as gender, health, migration, social interactions index (number of interactions that members of the household have with different actors: local government, institutions and other members in and outside the community during the last year) and size of the household were not included in the cluster analysis, but they were used as criteria to refine the clusters later on. For the hierarchical cluster analysis, a Wald's grouping method was used (Squared Euclidian Distance). The number of clusters defined was three, to classify households under the categories of *better off, average* and *poor*. This analysis was performed in SPSS version 16.0, taking into account the total households sampled in the research.

Economic diversification

For the analysis of economic diversification, every income source for the household in the last year was recorded. The cash income was calculated, taking into account time invested, related expenses or investments, and the income generated. After data collection, and based on Vedeld et al. (2007), the index of economic diversification was calculated independently of each case study using the diversification index proposed by Shannon-Wiever **DI**, where:

$$\boldsymbol{DI} = \sum_{i=1}^{s} Pi^2$$

Here, ***s*** represents the income from the different sources of income identified, and ***Pi*** is calculated as:

$$\boldsymbol{Pi} = \frac{ni}{N}$$

Here, ***ni*** represents the income from source ***I*** and ***N*** represents the total income in the household. Furthermore, the diversity index was compared between case studies by using the non-parametric Mann-Whitney U-test. Finally, the sources of income were grouped into seven categories: crop production, livestock production, natural resources related activities, out-farms activities, off-farm, remittance, and others (based on Vedeld et al. (2007); Table 3.7). The total income was calculated per category in USD/day for the analysis.

Table 3.7: Criteria used to categorize and measure the income sources identified in the highlands and inter-Andean valley.

Income source	Description
Crop production	The income from the five main economic crops was calculated (for marketing and home consumption), taking into account the difference between total revenue minus total expenses (purchase of seeds, fertilizers, pesticides, transportation to markets, and other expenses).
Livestock production	Income from selling livestock minus related expenses (veterinary, vaccination, food, and transportation).
Natural resources – related activities	The income in this category was calculated taking into account: 1) cash income from recollection and selling of medicinal plants, 2) fishing activities, 3) use of local natural resources to produce and sell local handicraft, minus all related expenses (material, transportation, time invested and labor).
Out-farm activities	The income in this category was calculated taking into account: 1) cash income for working in other farms as a daily labor or "*minka"*, 2) cash income from agro-tourism activities in the community and 3) honey production.
Off-farm activities	Activities that provide services and bring cash income constantly for the household: transportation, wage work, mining, trade and rental (housing or land), minus the difference of related expenses.

Continuation…

Income source	Description
Remittances and transfer (bonds)	The income in this category was calculated taking into account: 1) pension and retirement, 2) *Bono Dignidad* (monthly income paid by the national government to people older than 65) 3) *Bono Junacito Pinto* (paid by the government to children that attend school on a daily basis up to fifth grade).
Eucalyptus plantation	The income from *Eucalyptus spp.* plantation was calculated as the difference between total revenue from selling the wood minus total related expenses (purchase of seedlings, labor, transportation to market, others).

Based on Vedeld et al. (2007)

Independently of every case study, income sources were compared between wealth categories using a non-parametric test: Kruskall-Wallis for continuous variables. This statistical analysis was performed in SPSS version 16.0. Furthermore, and in order to determine the key factors that drive poverty and to relate differences in household traits to income from the different sources and overall wealth, a redundancy analysis (RDA) was performed using the CANOCO 4.5 software package. First, a detrended correspondence analysis (DCA) was carried out on household trait distribution data only. The longest gradient was 1.2 SD (SD=standard deviation of units of household trait turnover), and therefore, the response was linear to the gradients. Thus, RDA was used following Lepš and Šmilauer (2003) for gradients smaller than 3 SD instead of a canonical correspondence analysis (CCA), which would be the appropriate model for a unimodal response. The RDA was carried out with a focus on inter-sample distances. Household trait data was log transformed and the model was tested for significance by the Monte-Carlo Test (1000 permutations).

3.4.4 Social network strategy assessment

The definition of social networks refers to the social structure made up of actors (individuals, groups of individuals, organizations or countries) and interactions or ties among them arising from any kind of relationship between two or more actors (Sankar et al. 2015). The analysis of a social network provides the tools for understanding the organizational structures of

households in the community (Rico García-Amado et al. 2012), and contributes to identify 1) key actors forming the social network, 2) investigating the network architecture properties, and 3) the relationships between actors and the way in which groups of actors cluster together in social space (Morone et al. 2015; Sankar et al. 2015, Kilduff and Tsai 2005).

When analyzing the structure of a social network, several concepts must be considered. One of the most important refers to the centralization that is focused on the degree to which the network is centralized around one or a few actors. The centralization of a network has been extensively used to analyze the structure of the network and infer its function (Kadushin 2004; Kilduff and Tsai. 2005). Centrality measures the degree in which an actor or group of actors are connected to others in a network through relationships, experiences, or exchanges of goods and information (Ricciardi 2015). This tool allows quantifying the degree to which the actors are interconnected in the network (Sankar et al. 2015). Network research uses various centrality measures, the most popular are degree centrality, closeness centrality, betweenness centrality and eigenvector centrality. Each of these measures quantifies how close each node is to the central position in the network, but the concept of being central is defined in each case. Degree centrality indicates the number of neighbors an actor has and the amount of direct information one actor receives. Numerous studies have found that the degree centrality of actors has a positive influence on individual performance (Sankar et al. 2015, Hofstra et al. 2015).

The assessment of social networks starts with the assumption that relationships among community members and other social organizations are based on cultural traditions built over time among the actors. Hence, an individual identifies himself interacting with a particular individual or a group of individuals according to a particular situation, i.e. the share of agricultural labor between family members. In this example, the relationship or tie between family members is based on agricultural production. But beyond the relationship between community members and other social organizations is the interest of the individual to exchange goods and knowledge that rise from a particular scenario. Based on that, this research focuses attention on two scenarios: the first one, on the relationships among actors when socio-economic conflicts occurred and, the second one, on the relationships among actors when an extreme weather event affected the households. In both scenarios, the livelihoods of the households are compromised.

To assess how social networks conform based on these two scenarios (socio-economic conflicts and climatic hazards), the research explored the relationships between actors following three main questions: What kind of problem (socio-economic or climate-related) are you currently facing? Is anyone in the community or social organizations helping you to cope with this particular problem? What kinds of strategies are assumed to address these problems? The assessment contemplated four main steps: 1) identification and characterization of actors, 2) structure of the network, 3) network function 4) degree centrality and correlation analysis. The results are presented in a sociogram (Figure 3.8).

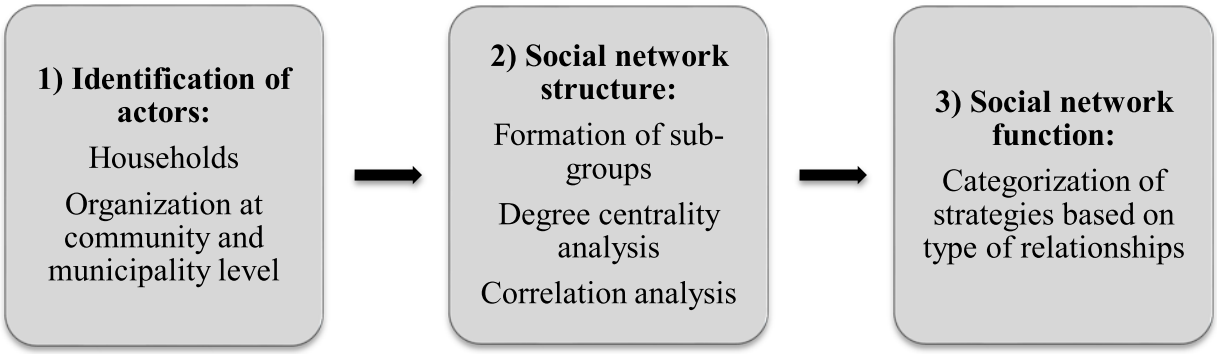


Figure 3.8: Phases for the social network analysis.

Identification of actors in the social network

The list of households participating in the survey has been considered a starting point to track down actors and relationships in the network. The "snowball method" has been used to identify all the actors and the corresponding ties in the network. This method begins with a focal actor or set of actors and each of these actors are asked to name some or all of their ties to other actors. Then, all the actors named (who were not part of the original list) are tracked down for some or all the ties (Burt 2000). In the case of the present research, this method has been slightly modified and all the actors named were tracked down only if they were present in the community during the research time. The snowball method has been complemented by local observations during official community meetings, school activities with families and informal conversations in town. Therefore, all the governmental and non-governmental organizations, directly related with the households, including syndicates, federations, and local enterprises have been identified.

Households and key informant interviews have been used to identify the type of relationships between the identified actors. Key informant interviews applied to the governmental and non-governmental organization, authorities in the communities and syndicates, federations and local enterprises. The interviews focused the attention on the objectives of the institution, programs and projects in course, materials and equipment, resources available, staff, and relationships with community members (full interview Appendix 1). Household interviews focused on the livelihoods of the families and the relationship between a pair of actors. The frequency of interactions between actors was a variable difficult to assess due to ambiguous answers that give the floor to different interpretations.

Social network structure assessment

The structure of the networks has been analyzed for both case studies: highlands and inter-Andean valley distinguishing: 1) social network between actors whenever a socio-economic conflict affected the households and 2) social network between actors whenever extreme weather events affected the household. Hence, four social networks have been identified and analyzed. The analysis included the development of sociograms characterized by nodes to represent the characteristic of the actors and ties to represent the relationship between actors (Kadushin 2004). Two software tools: UCINET 6.0 (Borgatti et al. 2002) and NetDraw 2.148 (Borgatti 2002), have been used to visualize the social networks structure. UCINET allowed computing a series of quantitative indicators such as centrality degree and NetDraw allowed generating different sociograms showing node attributes. Nodes have been represented by different symbols and sizes based on their characteristics and the ties have been represented with different colors based on the type of relationship.

A good drawing of a sociogram can immediately show some of the most important features of overall network structure. A binary measure of relationships was used to understand the relationships among the actors inside the social network. This is the most common approach to scaling relations. The first step was to identify the ties among actors, distinguishing between relations being absent (coded = 0) and ties being present (coded = 1; Table 3.8).

Table 3.8: Example of binary measure of relationship among actors (households)

HOUSEHOLD	HH1	HH2	HH3	HH4	HH5	HH8	HH9	HH10
HH1	0	0	1	0	0	0	0	0
HH2	0	0	0	0	1	0	0	0
HH3	1	0	0	1	1	1	0	1
HH4	0	0	0	0	0	0	0	0
HH5	0	1	1	0	0	0	0	0
HH8	0	1	0	0	0	0	1	1
HH9	0	0	0	0	1	0	0	1
HH10	0	0	0	0	0	1	1	0

Research own derivation

Further on, the structure of the network presented in the sociograms is calculated by the distance between actors using "k-core" analysis in the software NetDraw. k-core analysis defined the existence of a "group" or "sub-structure" that represent a set of nodes that are more closely connected to one another than they are to nodes in other k-cores in a sociogram.

Centrality measurements focused the attention on degree centrality, defined above as the number of ties that every actor has. This measurement has been calculated with the software NetDraw and represented in the sociograms by using different node sizes. Further on, the centrality degree was correlated with income data per household to determine a potential relation between these two variables. Correlation analysis has been calculated using the SPSS software.

Social network function assessment

The network function analysis highlights the strategies implemented by a pair of actors to address a particular problem. Therefore, the relationship between a pair of actors has been defined using a multiple-category nominal measure of relations. Five categories of relationship among the actors have been identified based on the strategies used to cope with a particular situation (Table 3.9).

Table 3.9: Identification and categorization of strategies implemented in the network based on 108 interviews from the highlands and inter-Andean valley.

Strategy	Description
Agricultural production	Refers to actions focused on: soil management, seed renovation, pest control, implementation of irrigation system, and increment of daily labor for agriculture.
Organization and planning related activities	Refers to activities focused on: risk management, education, health care, basic services, road improvements, community budget, local regulations, agreements between local actors and social organizations, implementation and monitoring of projects and regulation and uses of natural resources.
Health care related activities	Provide health care to local families
Local initiatives	A group of community members have developed a new association, enterprise and / or were taking part in a project with the objective to improve the quality of life inside the household. These activities required additional skills and knowledge from the households and provided an additional source of income.
External support	Local households received constant support in remittances or labor from relatives living outside the community.

Research own derivation based on household survey

4. INTEGRAL DIAGNOSIS

4.1 Highlands case study

4.1.1 Population – general characteristics

The lifestyle in the community of Santiago de Okola developed around agricultural activities and cultural traditions which also depend on the seasons. Every year during the rainy season, all families gather and share agricultural tasks, and the fields are covered with crops showing the rich characteristic agrobiodiversity of the region. The dry season is a time of quiet, the conditions of the land limit agricultural production and young people migrate to other areas leaving the community in the hands of older people and young kids.

Extended and nuclear families have been identified, being extended families more common to observe, where three generations (grandparents, parents, and children) live together in the same household and sometimes also with other relatives; for example uncles, nephews or cousins. The number of family members varies during the year, between one and two adults living permanently in the community mostly at an older age (61 years old in average; Figure 4.1). Moreover, 40% of the household heads are women. The level of formal education of families remaining in the community is low, mostly the men reached the fourth grade of primary school and the women just the first. But currently, Santiago de Okola hosts more than 100 students from neighboring communities in the municipality. The school has teachers for the 12 grades including primary and secondary education.

Figure 4.1: Elder people living permanently in the community of Santiago de Okola.

The number of people living in the community is constantly changing, as the population between 15 and 40 years old is constantly migrating to the cities of La Paz and El Alto, but also to other countries like Brazil, Argentina, and Spain. Part of the population migrates permanently due to lack of land and in search of new job opportunities to places where they can find a stable income or where they are able to follow an education program at a technical level, after finalizing a high school education. Another part of the population migrates for short periods of time mainly due to lack of income during the dry season. In this case, mining in neighbor communities or the work in construction or as merchants become attractive options.

In terms of infrastructure, the household houses have been built with adobe and in some cases, the walls have not been covered. They consist of 3.5 rooms (on average) with a ratio of 1.8 persons per room. The rooms are designated for sleeping and cooking purposes. Every household has external pipes with drinking water and external latrines since the 1990s. In terms of health care, most of the families that live permanently in the community use medicinal plants for health problems like stomachaches, headaches, colds, and fevers. There is one health center with the capacity to assist people with basic health problems. The center is open two times a week, but the resources are limited. Whenever families need attention they have to travel to Carabuco (the capital of the municipality) located 45 minutes away by car, or to the cities of El Alto or La Paz.

Symbols of the culture in the community are the management of agro-biodiversity, the weaving of colorful textiles, the knowledge of medicinal plants, the weather forecast knowledge; all of them are related to the agricultural calendar as explained in the next chapter.

4.1.2 Agriculture

Like many other communities on Lake Titicaca, in Santiago de Okola the agriculture goes back to the times of first civilization settlements in the region. Along the history of the region, the agriculture in the area has developed due to adaptation strategies to cope with climate variability and the management and conservation of a variety of Andean crops. Andean agriculture is organized mainly around family farms and characterized by low production scales mainly for self-consumption, and to some extend for the local market. Several

institutions have contributed to the conservation of Andean varieties with special attention to potato and quinoa varieties. Twelve different crops have been identified (Figure 4.2).

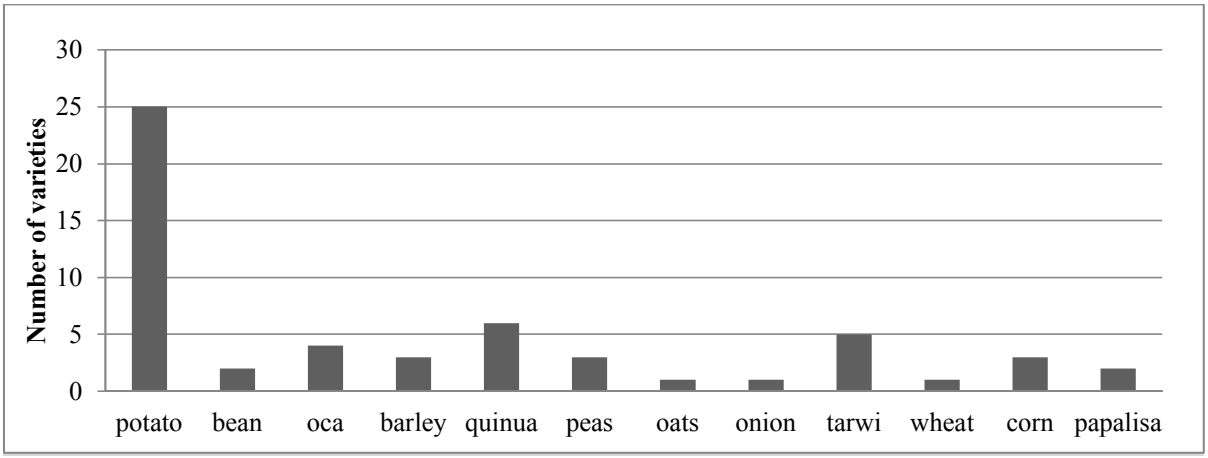


Figure 4.2: Crops identified in 61 households during the research in the highlands.

The development of these crops depends on the rainy season, and its productivity is limited to different factors, for example, the climatic variation and the occurrence of extreme weather events. Farmers in the region live in a permanent status of uncertainty not just related to climatic variability but also to market conditions. The farmers are not able to regulate the prices of the product in the market and they depend entirely on the supply and demand for products during the harvesting season, whenever the product is in abundance in the market, the price is very low and does not cover the expenses of production. In that case, farmers secure food production by applying different techniques to transform and process food. For example, the production of "*chuño* and *tunta*" (dehydrated potato).

Since 2010 local and external organizations are joining forces to evaluate a preliminary assessment and propose a plan for the implementation of an irrigation system. Currently, this project is not working and community members are demanding an irrigation system. The access to drinking water is reduced during the dry season, as only a few families that have land in the upper part of the community have better access to different sources of water that help them grow vegetables for self-consumption in small plots.

Agricultural activities are complemented by livestock, mainly sheep (average of 10 heads per family), but also pigs and chicken for self-consumption. The families designated different

land to feed livestock. During the dry season, most of the animals are sold in local markets because it is more difficult to find good quality grassland.

4.1.3 Forest resources

The conservation of the Andean forest in the area of Lake Titicaca is critical. In the community, just a few individuals of *Polilepis sp.* have been identified as having an ornamental use in some of the houses. As many other communities in the region, most of the households have a small plot of eucalyptus. There is no management plan for this species, and most of the households use this resource as an insurance so that whenever the crop production is low, people sell one or two as firewood or for construction.

4.1.4 Socio-economic problems of the households

The population of Santiago de Okola declared the existence of several difficulties that households are facing currently. These problems have been grouped into eleven categories (Figure 4.3). More than 70% of the households have experienced losses in production, families did not have enough food for their own consumption and they needed to purchase from different sources. More than 60% of the households have declared that they did not have enough products to sell, and if they did, the quality was low while the competition with other communities was high. More than 60% of the households have declared that they were not able to work the land on time because health problems or just because they are very old and have severe limitations. Less than 50% of the households declared water conflicts mainly during the dry season. The water supply during the last year has been reduced and the access to drinking water during the dry season was limited to a few hours during the day.

A total of 30% of the households claimed that the authorities and the community members are not well organized, which causes problems inside the community. For example, the performance of community work is not well-designed. Less than 20% of the households declared to have land delimitation problems with their neighbors, but also, some households do not have enough land for their children, which is why they have to migrate to different areas. Migration is perceived as a problem for less than 20% of the interviewed households, and they related migration with the lack of labor for agricultural production. Problems with infrastructure, lack of basic services and conflicts inside the family were mentioned by less than 10% of the households.

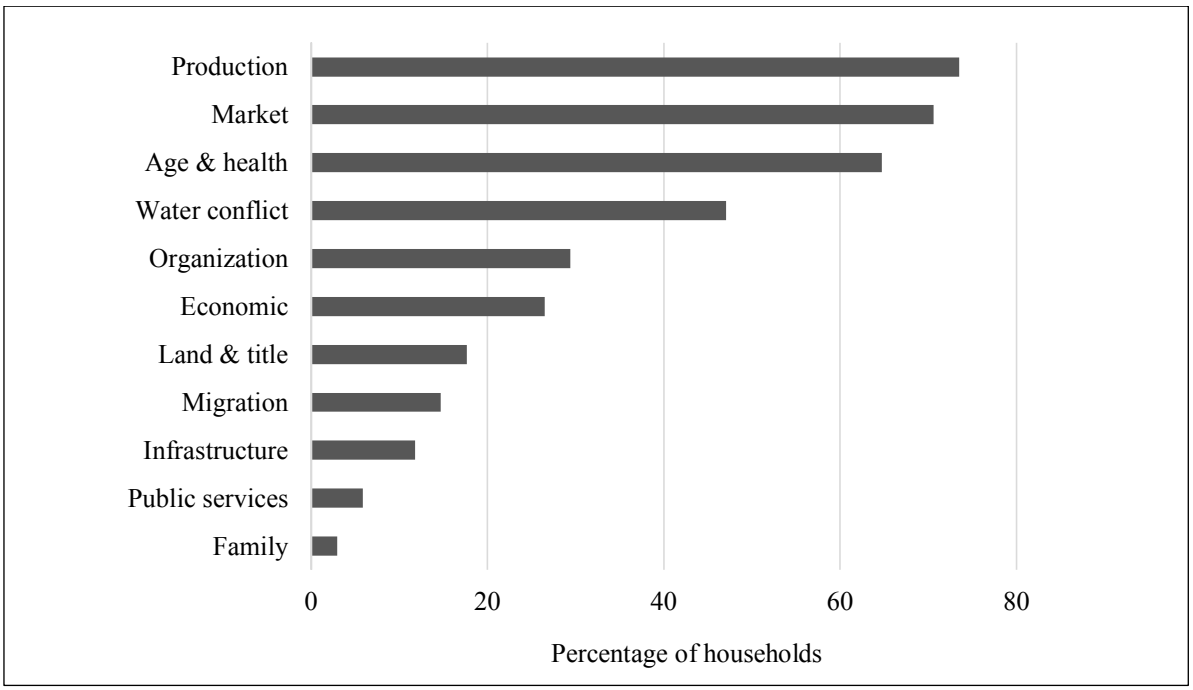


Figure 4.3: Socio-economic conflicts identified in the highlands based on 61 households interviews during the survey.

Strategies to cope with production loses, organization, health, and lack of economic resources were identified during the survey (Table 4.1).

Table 4.1: Strategies use by households in the highlands to cope with socio-economic problems identified during the household survey.

Socio-economic problem	Coping strategy	(% of households)
Production	access to food in local markets	2
	use of irrigation systems	17.64
	storage of food	2.94
	labor contracts	5.88
	use of artificial fertilizers and pesticides	5.88
	soil management traditional techniques	5.88
Organization	ask for help from authorities in charge	14.70
Age & health	health-care centers in nearby city	14.70
Economic	ask for help from relatives outside the community	20.58

Own research derivation based on 61 household interviews.

Based on the survey, a few recommendations were identified, 40% of the mentioned recommendations point out the importance of new sources of water and the implementation of water pumps to satisfy the need of irrigation for crop production. At the same time, households identified the role of the municipality as crucial to bringing new alternatives to improve crop production and the implementation of a risk management strategy.

4.1.5 The impacts and strategies to cope with extreme weather events

Based on the household surveys and group discussions, changes in the annual season were recorded in the last years. Farmers declare that "*the weather is changing and every year is different*, *the rainfall is unpredictable and with mayor intensity; the sun in winter is very strong and does not heat at all"*. Thus, the occurrence of four main extreme weather events has been identified during the research period: intense rainfall in short periods of time, a prolonged drought season, severe hailstorms and frost (Figure 4.4).

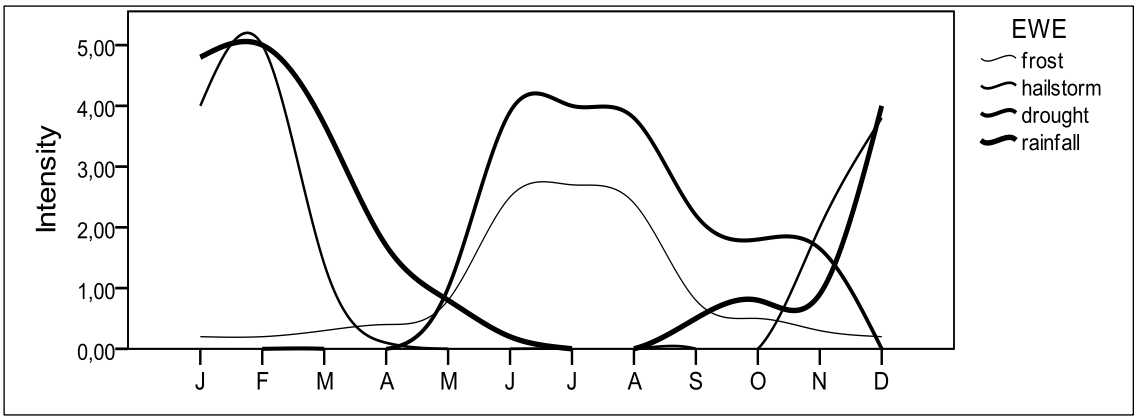


Figure 4.4: Intensity and seasonality of extreme weather events (EWE) in the highlands during the research period 2013-2014, based on 61 household interviews; where 0 = no intensity and 5 = high intensity.

Households expressed concern on the impacts that extreme weather events are having on their livelihoods. Based on the household survey from 2013 and 2014, the percentage of households affected by extreme weather events has been calculated (Figure 4.5).

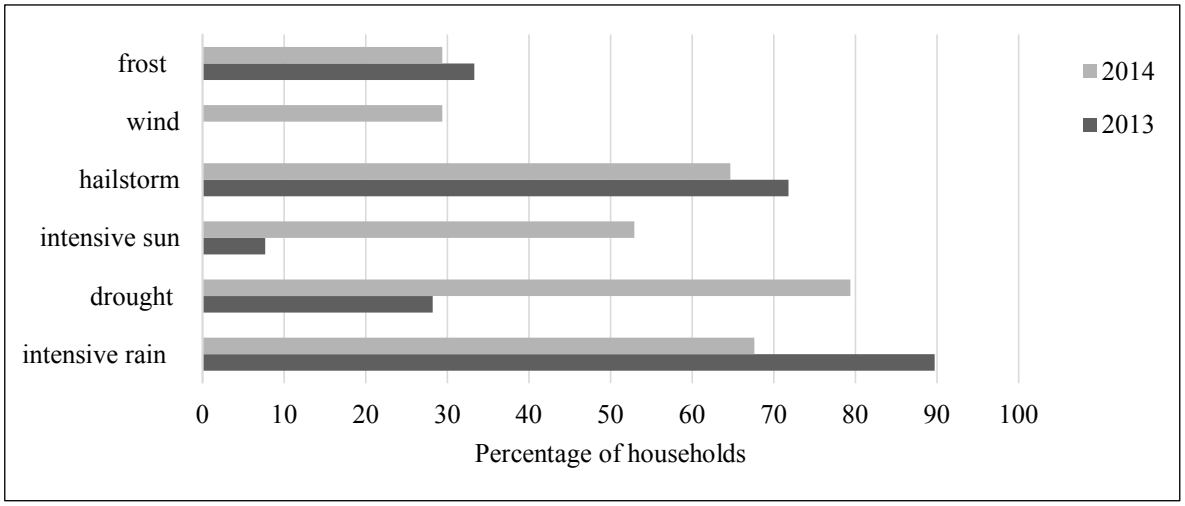


Figure 4.5: Percentage of household affected by extreme weather events during the research period; based on 61 household interviews.

Impacts and strategies to cope with intensive rainfall

Farmers reported the beginning of the rainy season as unpredictable. The intensity and duration of this season are erratic. Instead of long seasons with little precipitation, farmers reported short but intensive events of precipitation. The consequence of this phenomenon is reflected in the percentages of households affected by floods, river floods and pest attacks (Figure 4.6). Farmers reported more damage caused by floods in 2013. This event has occurred mainly in the lower area of the community "Las pampas" (flat land in the community), where standing water was above the surface from 5 to 10 cm. Moreover, the flooding of the "Calajawira River" has increased to three time its original size, causing damage along its course, especially in cultivated land (Figure 4.7).

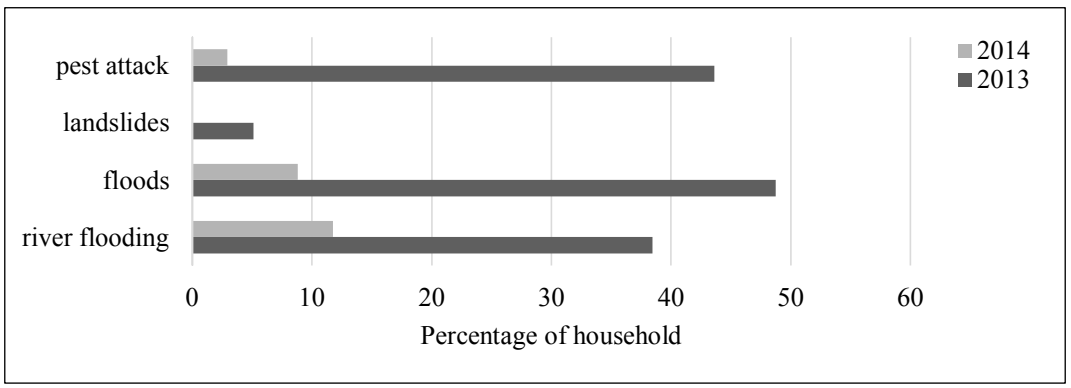


Figure 4.6: Percentage of households affected by the impact of intensive rainfall during the research period, based on 61 household interviews.

Figure 4.7: The impact of intensive rainfall in the highlands (2013): Flood of cultivated areas (left), damages in potato crop (right).

During the research, a total of six main rainfall impacts have been identified. Most of the households experienced losses in production followed by soil damage, infrastructure damage, no access to the market and livestock damage (Figure 4.8). The standing water on the field crops produced rotting of the potato crops much earlier than harvesting time. For those crops under water, farmers didn't have the opportunity to harvest seeds, and most of the production was lost. Livestock damage was measured by the number of sick cattle as a result of increased moisture. Among infrastructure damage reported, the most common were moist walls and damage in the corrals.

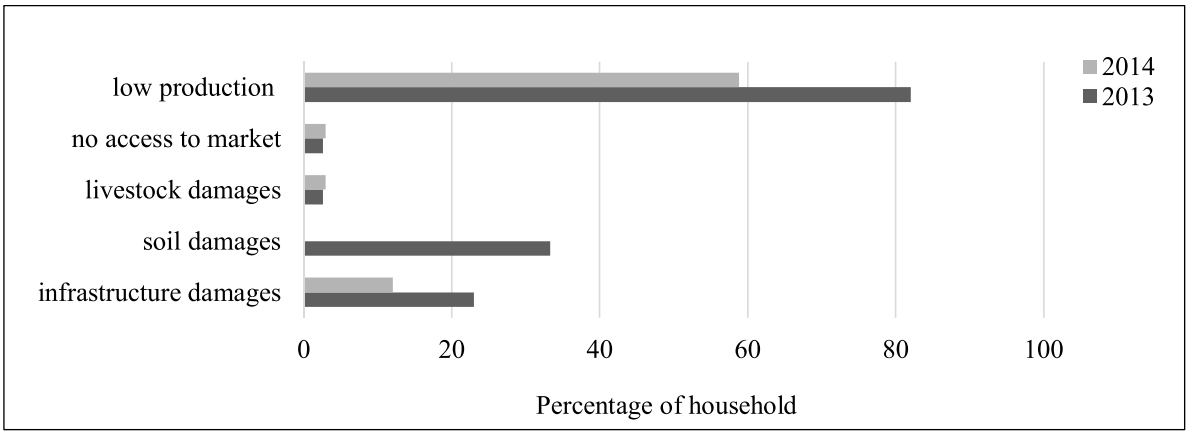


Figure 4.8: Damages of livelihood resources as a consequence of intensive rainfall in the highlands based on the percentage of households affected. Information collected from 61 household interviews.

The strategies used by farmers to cope with the impacts of intensive rainfall relied on the traditional and modern knowledge of agricultural practices, such as the use of natural fertilizers, fallow land, crop rotation and others (Table 4.2). Based on the survey, households declared that community members worked on the canalization of the river Calajawira. Nevertheless, the efforts on dredging the river beds to avoid flooding were not enough due to the lack of economic resources and limited support from the municipality providing tractors and bulldozers.

Table 4.2: Strategies used by farmers to cope with the impacts of intensive rainfall in the highlands based on 61 interviews.

Impact	Coping Strategy	2013 (% HH)	2014 (% HH)	Effect
Agricultural production	use of climatic indicators (*)	51,28	26,47	Null
	digging of channels	17,94	14,70	+
	use of pesticides	74,35	5,88	+
	changes on production cycle/ harvesting	20,51	0	+
	crop rotation	2,56	5,88	+
	purchase of seeds	2,56	0	+
	use of live barriers (eucalyptus)	2,56	0	+
No access to market	help from local government	2,56	2,94	+
Infrastructure	reinforcement of infrastructure	2,56	0	+

Own research derivation based on the household survey where % HH = percentage of households. (*) climatic indicators based on traditional knowledge are described in detail in section 5.1.2; Table 5.1.

Despite the local concern on the impact of intensive rainfall among the local population, not many recommendations have been proposed by the households. Most of the answers in the highlands suggest that they need more support from local government (Figure 4.9).

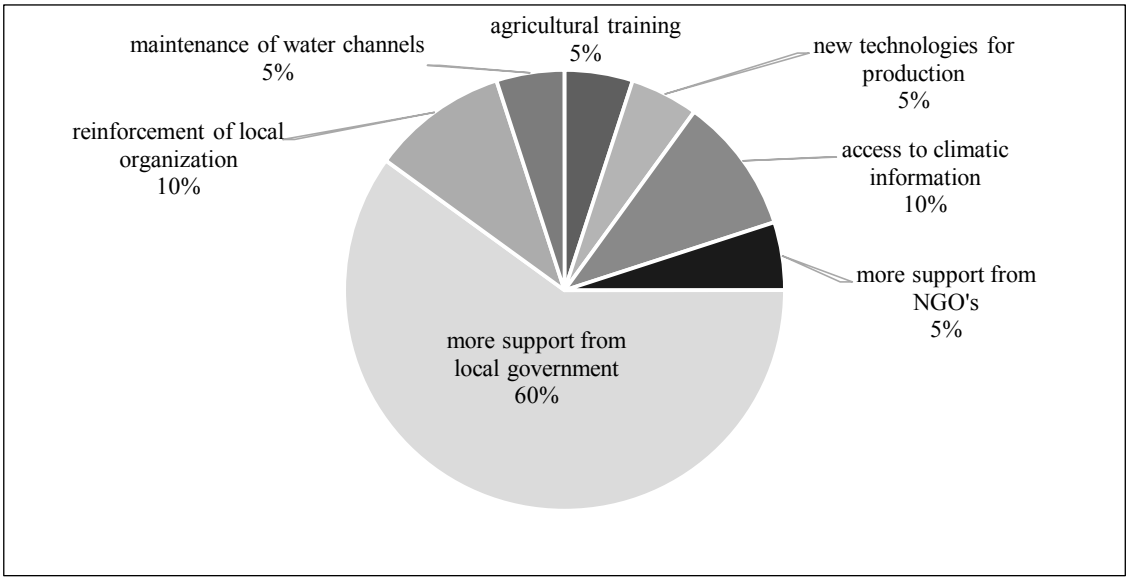


Figure 4.9: Local recommendation to cope with intensive rainfall event in the highlands

Impacts and strategies to cope with prolonged drought

A total of 8 negative impacts have been identified as a consequence of the prolonged drought season mainly during the second year of research (Figure 4.10), with most of the household having experienced agricultural losses. Access to drinking water during the first year did not represent a problem because most of the households have a pipe in the backyard and access to drinking water year-round. But during the second year of research, the amount of water was notoriously diminished because the main sources, the rivers from the glacier were also reduced. This year the lack of water for animals was critical for more than 20% of the households. Increased soil erosion was perceived by 15% of households.

Moreover, during this year households delayed the planting season and increased work effort and labor due to the dry conditions of the soil (Figure 4.11). The first planting in October failed because it depended entirely on the rain to grow. Finally, a minimum percentage of farmers that participated in the surveys reported a loss of agrobiodiversity due to the prolonged drought season. Farmers were not able to cultivate different varieties of quinoa and potato, the most economic important crops in the highlands.

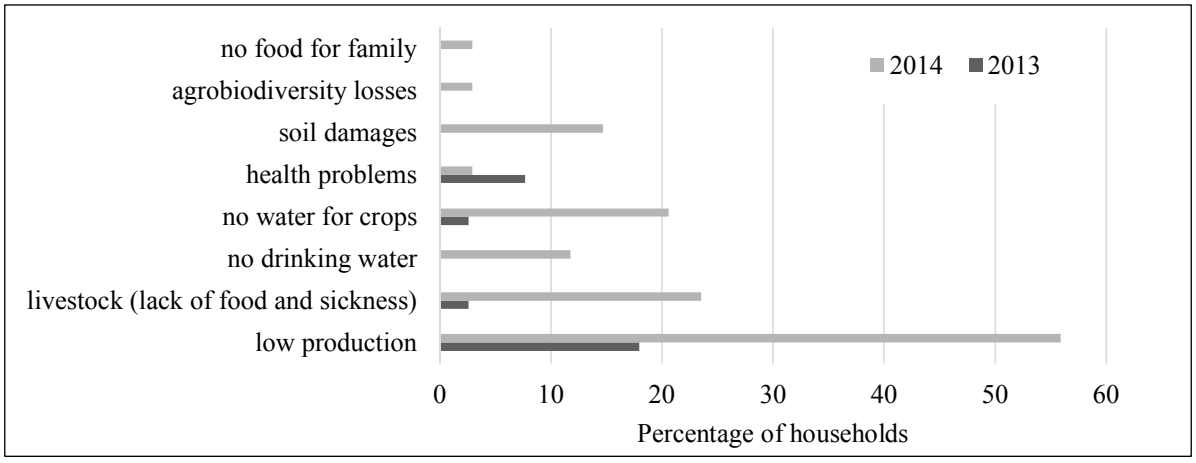


Figure 4.10: Percentage of households that have been impacted by prolonged droughts during the research period in the highlands. Information based on 61 household interviews.

Figure 4.11: The impacts of prolonged drought season in Santiago de Okola – Highlands, December 2014. Irrigation channels without water (left), soil erosion (right).

Registered coping strategies used by farmers to maintain agricultural production followed a prolonged drought period focused on food storage, an increase of labor, the performance of traditional rituals, soil conservation techniques and implementation of the irrigation system Table 4.3). Other strategies were: storage of food for animals, selling livestock before a drought period, diversification of products, transporting water in drums, canalizing the water, giving time to the land to rest and walking long distances with livestock looking for grassland.

Table 4.3: Identification of strategies to cope with prolonged drought season in the highlands based on 61 households interviews.

Impact	Coping Strategy	2013 (% HH)	2014 (% HH)	Effect
Livestock	food storage for animals	2,56	2,94	+
	pasture for livestock outside the community	0,00	2,94	+
	help from local government	2,56	0,00	
No drinking water	bring water in drums	0,00	2,94	+
No water for crops	maintenance waterways	0,00	2,94	+
	use of irrigation system	7,69	11,76	+/-
	help from local government	7,69	0,00	+/-
Low production	changes on production cycle/harvesting times	10,26	0,00	+
	use of traditional rituals (*)	10,26	32,35	Null
	increase of labor	41,03	73,53	
Agrobiodiversity losses	product diversification	0	2,94	+
Soil damages	soil conservation techniques	0	35,29412	+
Health problems	decrease in working hours	7,69	0	-
No food for the family	food storage	97,4359	64,70588	+

Own research derivation based on the household survey, where %HH = percentage of households. (*) detail description Table 5.1

In the highlands, 49% of the recommendations given by farmers were related to the implementation of irrigation systems, which require research for new sources of water, external support from authorities and new investment in pumps and pipes (Figure 4.12). Despite the location of the community on the lakeshore, the chemical characteristics of the water do not allow the farmers to use this resource for irrigation. The concentration of salt would damage the soil in a short period of time, making the land not suitable for agriculture purposes.

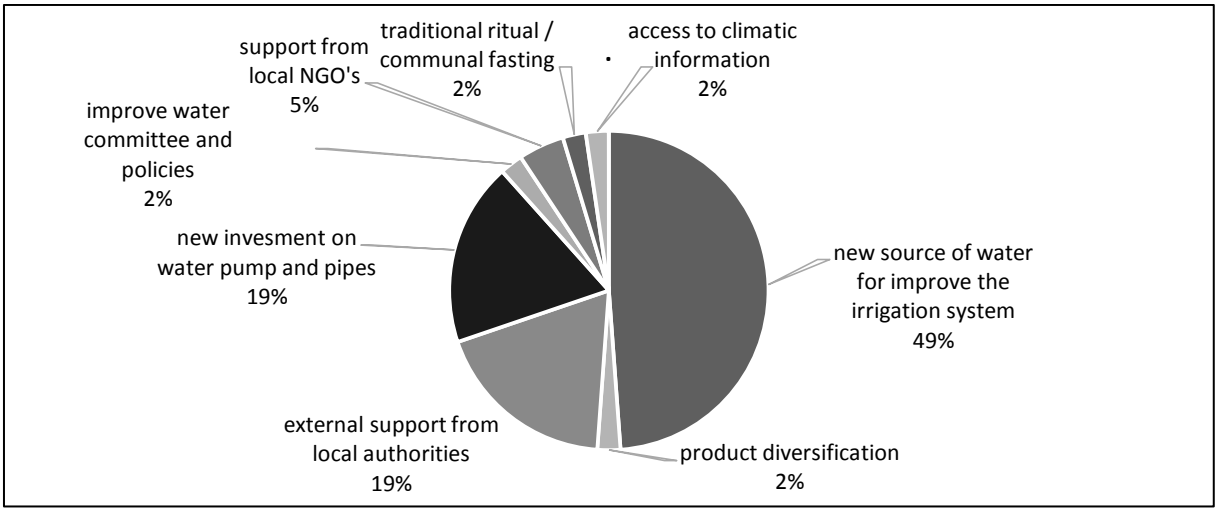


Figure 4.12: Local recommendations to cope with the prolonged drought season in the highlands.

Impacts and strategies to cope with hailstorm

The first year of research, households were more affected by the occurrence of hailstorms than the second year. Farmers have manifested that after a hailstorm the concentration of hail in the ground increased soil water stress, bringing a direct impact on the potato production; this crop is extremely sensitive to get rotten inside the ground before the harvesting time. Further on, the hailstorm is responsible for physical damage to the corn leaves and potato flowers (Figure 4.13). The outcome was low quality of the product and yield reduction. Additionally, hailstorms are responsible for damage to the infrastructure: house and corrals, smashing walls and ceilings (Figure 4.14).

Figure 4.13: Damage to the potato crop due to excessive water in the soil after a hailstorm (left) and physical damage in the corn leaves (right).

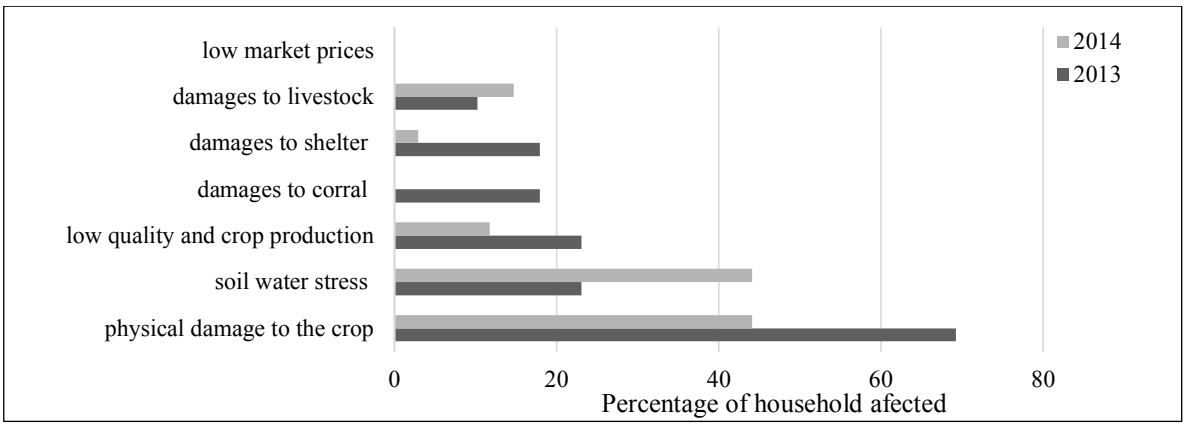


Figure 4.14: Percentage of households affected by hailstorms during the research period in the highlands. Information based on 61 household interviews.

The identified coping strategies have shown the importance to prevent the hailstorm by applying local techniques such as the use of salt, firecracker, and dynamite. The use of firecrackers is the most popular technique and few farmers relied on the use and performance of traditional rituals as a coping strategy to prevent yield reduction (Table 4.4). Currently, community members have the agreement to light firecrackers at the same time to have a better impact on stopping the hailstorms, also this strategy is well regulated by local authorities. On the other hand, the use of dynamite is not very popular because of the level of danger that it implies for the farmers.

Table 4.4: Identification of coping strategies to prevent the impact of hailstorms and agricultural losses.

Impact	Coping strategies	2013	2014	Effect
Crop damages - soil damages - yield reduction - animal damages	use of salt	5,12	0	+/null
	stoked	17,94	5,88	+
	firecracker	30,79	55,88	+
	dynamite	15,38	2,94	+
	use of traditional rituals	7,69	2,94	+
Infrastructure damages	corral reinforcement	0	5,88	+

Own research derivation based on household survey.

Two main recommendations have been identified with the participation of the farmers (Figure 4.15), community work (50%) and the reinforcement of social organization (30 %). The first

one outlines that all members of the community must act collectively to fire off firecrackers, but even though local regulations exist, not all farmers participate when required. Therefore, by reinforcing community work and social organization the impact of using firecracker can improve significantly. Another local recommendation points out the use of greenhouses, but this measure did not work out in previous years. Finally, another recommendation points out the performance of rituals as a measure to cope with hailstorms. This recommendation was named mainly by elder people in the communities, who blame the lack of rituals as responsible for the climatic variation.

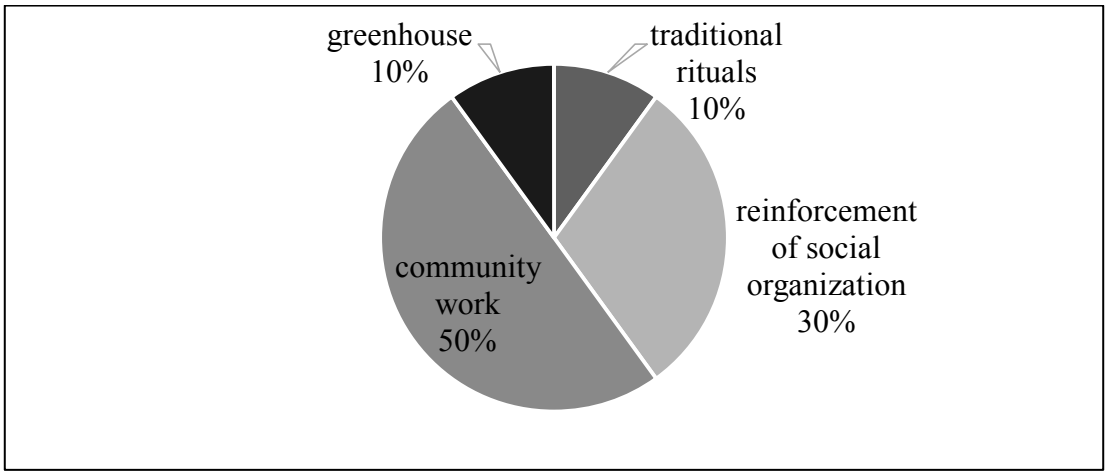


Figure 4.15: Local recommendations to cope with hailstorms in the highlands, based on 61 household interviews.

Impacts and strategies to cope with frost events

Frost plays an important role in the production of *chuño* (dry potato). The non-occurrence of frost events in June and July has a direct impact on this product as the process of transformation requires low temperatures. More than 25% of the farmers have reported unsuitable temperatures, therefore, low rates of *Chuño* production. The occurrence of frost events during the crop growing season have a direct impact on the flowering and growing of the potato and oca in the highlands (Figure 4.16).

As a strategy to cope with frost events farmers carry their potato production to other higher areas looking for lower temperatures to produce "*chuño*", but the level of work needed sometimes does not compensate the effort of the farmers. Also, farmers expressed concern about the lack of knowledge or alternatives that can substitute the "*chuño*", not just in terms of market product but mainly for self-consumption.

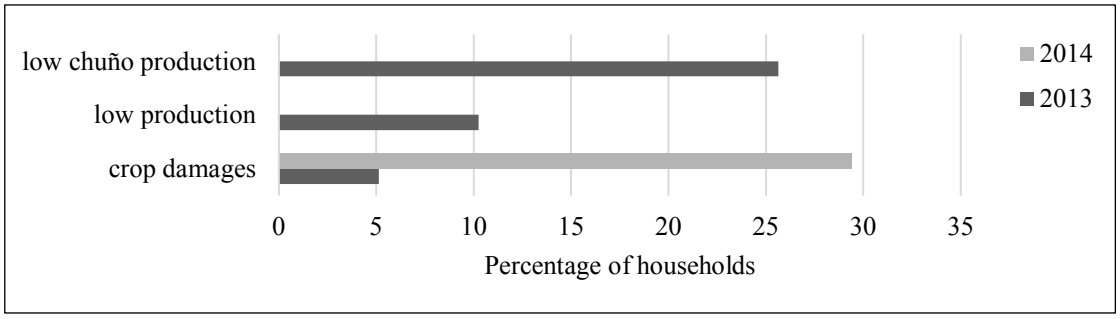


Figure 4.16: Percentage of households affected by frost events based on 61 household interviews.

4.2 Inter-Andean valley case study

4.2.1 Population – general characteristics

Family composition in the inter-Andean valley followed a nuclear structure (parents and children living together, an average of 4.3 children per family), but older couples living together have also been recorded. Based on household interviews, 45% of household heads were women with an average age of 51 years. The level of formal education for older people is very low, between first and third grade. Currently, students have the opportunity to stay in the same community to follow a formal education. The community of Sita hosts students from 6 neighboring communities, and the school offers education for all grades, from primary to secondary education. Even though this is a public school, families need to invest in uniforms, school supplies and time for school activities. In the community of Chorocona, there is a small multigrade school, meaning there is one single classroom and one teacher in charge of preparing teaching material for students from first, second and third grade.

Houses are very rustic, and most of them have been built from clay bricks. The houses have between 2 and 3 rooms designated to sleep, or for storage and cooking activities. Families with better incomes have built their houses with bricks. Just a small percentage of houses have toilets. The relationship of the number of relatives sleeping per room is 2.07 people. All interviewed households use firewood for cooking and just 35% of them also use gas when needed. The community has footpaths that connect the houses and other buildings. All families use public transportation to travel to the capital of the municipality or La Paz, while 2% of families use private motorcycles for local transportation. The distance from the house to the main road is on average 15 minutes walking.

Access to water is available in the community but its distribution is disproportional among the population. On one hand, 95% of the families have water for drinking purposes all year around, from which just 10% of these families have water for irrigation all year around and 50% have irrigation in at least one plot for agriculture. On the other hand, 5% of the families have limited access to water, and during the dry season, they have to walk for about one hour to collect water from the river for drinking and cooking purposes.

A total of 13% of the families reported that one member of the family presents of a chronic disease, 15% reported that one member of the family requires special attention, and 44% of the families report that during the last 3 months one member of the family was not able to work or attend school because of health problems. The communities don't have a health center, and families must travel to the main capital of the municipality in Inquisivi (17 km) or Quime (47 km). Whenever the attention is not possible in the capital, then the families have to travel to the cities of La Paz or El Alto depending on the health problem. Just 4% of the households interviewed have health insurance. Therefore, most of the households use local medicinal plants to take care of health problems

A total of 120 families are officially registered in the community. Yet, less than 80 families are living permanently in the area and the young members of the family are constantly traveling in search of different opportunities. The migration rate registered was high, an average of two people from each family migrate temporarily or permanently to neighboring communities to work on agriculture and mining, or to the cities of La Paz, Cochabamba and Santa Cruz looking for different jobs or education activities. A smaller proportion of migration to other countries also occurred, mainly to Brazil and Argentina and a small percentage to Spain.

4.2.2 Agriculture

The lifestyle in the communities is centered on agriculture. The friendly conditions of the environment allow families to produce vegetables for self-consumption all year round. At the same time, families access different products by "*trueque*", a traditional way of bartering with other communities in different locations. Currently, the principal crop in the area is the peach. This fruit has been introduced in the area 25 years ago by one of the families living in the community, and due to its success, neighboring families have started planting peach trees in

their plots. Today every family in the area has at least one plot of peach. The high production of peach was in the early 2000s, every family produced between 8 to 9 tons per hectare. Currently, and due to different problems related to pests and diseases of the plants, the production has been reduced to 2 or 3 tons per hectare. At the moment, agricultural insurance is available in the communities, peach production is not included. Therefore, losses of peach production represent a significant impact on the economy of the local farmers.

The development of agriculture started at the end of the 1990s with the cooperation of governmental and non-governmental organizations working in the area. The development was very fast introducing crops diversification and promoting land use change from natural forest to agricultural land. Currently, families are able to produce more varieties and designate part of the production to the market, for instance: corn, potatoes, wheat, green peas, peanuts, apples, squash, pears, custard apples, pacay, plums, kidney beans. Also, families have garden crops in their homes for self-consumption, for instance: onions, carrots, tomatoes, lettuce, barley, cabbage, and other vegetables. As a consequence of this fast development of agriculture, there are no well-established practices of soil conservation despite the efforts of institutions and NGOs working in the area. For example, the construction of terraces demands much labor and availability of rocks, both resources lacking in the area. Therefore, the soil erosion problems are becoming more visible.

4.2.3 Forest resources

The native vegetation in the area is composed of species of spiny scrub and small trees. Among the representative species are: *Acacia* sp, *Prosopis* sp, *Dodonaea* sp, *Ephedra americana*, *Polylepis* sp, *Schinus molle*. It is also possible to find a wide variety of woody resources. However, *Eucalyptus globulus*, introduced in the 1970s, was and still is one of the species with fast expansion in the area displacing native forest. Currently, the community is surrounded by extensive areas of eucalyptus plantations, and most of the families have at least one plot of this species.

A management plan for eucalyptus has not been registered in the area, but the timber harvest of this species can start in the fifth year of the plantation. Local households commercialized the product in two ways, by a number of trunks or according to the plot size. Both ways represent a significant source of income for the households. Families rely on this resource as

insurance for agriculture, and they sell this product only when needed. At the moment, the municipality is developing a program on reforestation with native species, for which they are building a nursery near the village of Inquisivi and experimenting with local species like *Acacia sp, Prosopis sp,* and *Dodonaea sp*. By the time the research was concluded, no progress of this plan has been observed.

However, during the research, further use of the forest has not been registered. Müller et al (2014), reported that traditional agricultural communities in the inter-Andean valley do not play a very important role in forest conversion or use. Basically, the forest represents a source of firewood for domestic use. Moreover, the forest area is communal land also use for livestock (VMMABCC 2009).

4.2.4. Socio-economic problems of the households

The diagnosis of the inter-Andean valley showed the existence of several difficulties that households are facing. The identified problems have been grouped into ten categories (Figure 4.17). Almost 30% of the households have reported market-related problems. For instance, the road conditions represent a barrier to taking the products to the market on time, and the instability of prices brings a low-income rate to the local farmers. 27 % of the population has declared problems related to economy of the household, for instance, lack of money to purchase food and other goods and lack of employment opportunities in the community. 24% of the households reported conflicts related to production, health and age, and water.

Problems related to production are rooted in the lack of alternatives on the management of peach plantations, lack of skills to develop new crops, lack of new technologies and the lack of renovation of seeds, together with soil degradation. Farmers are concerned about the soil quality as it is becoming very poor. Age and health represent less labor available for agricultural work, and water conflicts refer to the lack of this resource for some of the families but also for internal conflicts among households in the community because the use and distribution of irrigation systems are not yet well-regulated. About 15% of households declare land delimitation conflicts with the neighboring families, and problems related to infrastructure are related to road conditions. Around 5% of the households mentioned problems related to public services. They demand a new healthcare center in the community and social conflict arises between social organization and inside the families due to lack of

communication and conflicts of interest. Based on the survey, some strategies to cope with the mentioned socio-economic conflicts have been identified (Table 4.5).

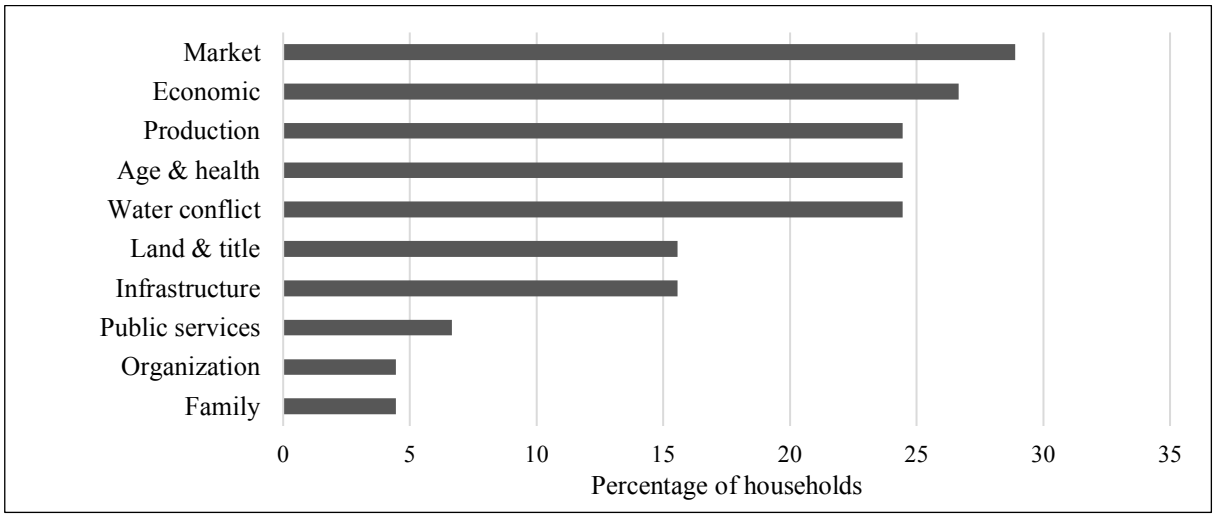


Figure 4.17: Socio-economic conflicts identified in the inter-Andean valley case study, based on 64 households' interviews during the survey.

Table 4.5: Strategies use by households to cope with socio-economic problems identified during the survey.

Socio-economic problem	Coping strategy	Percentage of households
Production	use of irrigation systems	76.92
	use of artificial fertilizers and pesticides	2.56
Organization	ask for help from authorities in charge	25.64
Infrastructure	team work on road, channels for water	2.56

Own research derivation based on 64 household interviews.

Based on the survey, a few recommendations were identified. 50% of the mentioned recommendations point out the importance of new sources of water and the implementation of water pumps to satisfy the need of irrigation for crop production. At the same time, households identified the role of the municipality as crucial to bringing new alternatives to improve crop diversification (Figure 4.18).

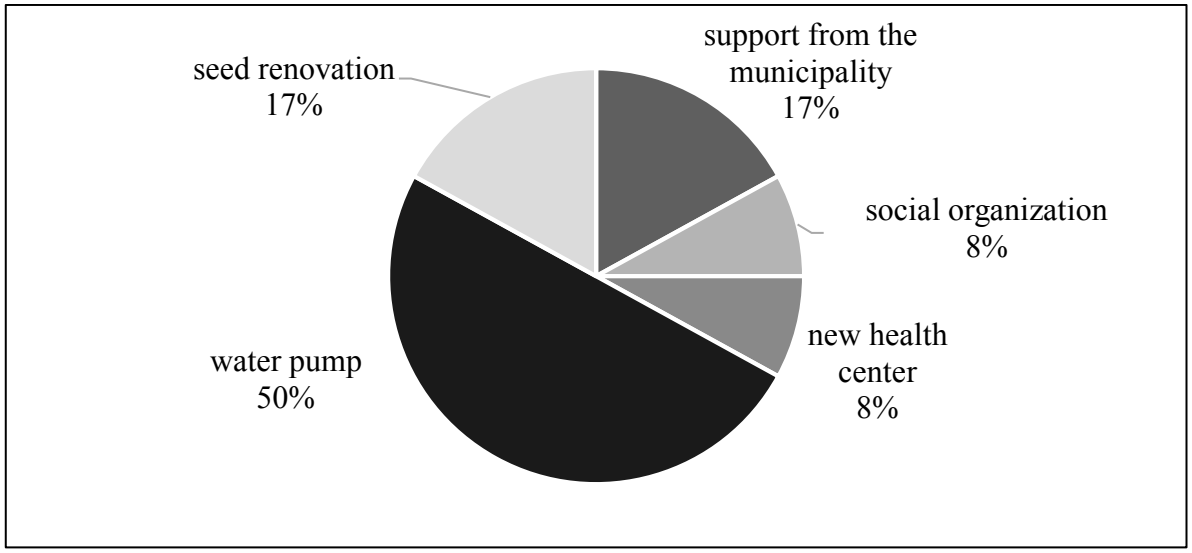


Figure 4.18: local recommendation to cope with socio-economic conflicts based on 64 household interviews.

4.2.5 The impacts and strategies to cope with extreme weather events

In the inter-Andean valley changes in the annual season were also recorded in the last years. Five types of extreme weather events have been identified: intense rainfall in short periods of time, a prolonged drought season, strong winds, scattered hailstorms and few events of frost. The intensity of these events depends on the season and present variation during the year (Figure 4.19).

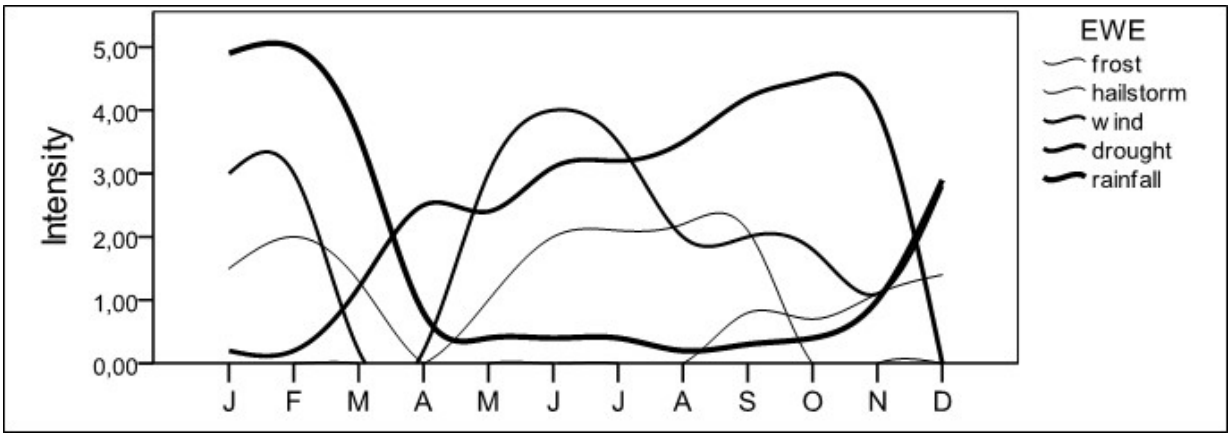


Figure 4.19: Intensity and seasonality of extreme weather events (EWE) in the inter-Andean valley during the agricultural year 2013- 2014, based on 64 household interviews; where 0 = no intensity and 5= high intensity.

Households expressed concern on the impacts that extreme weather events are having on their livelihoods. Based on the household survey from 2013 and 2014, the percentage of households affected by extreme weather events was calculated (Figure 4.20).

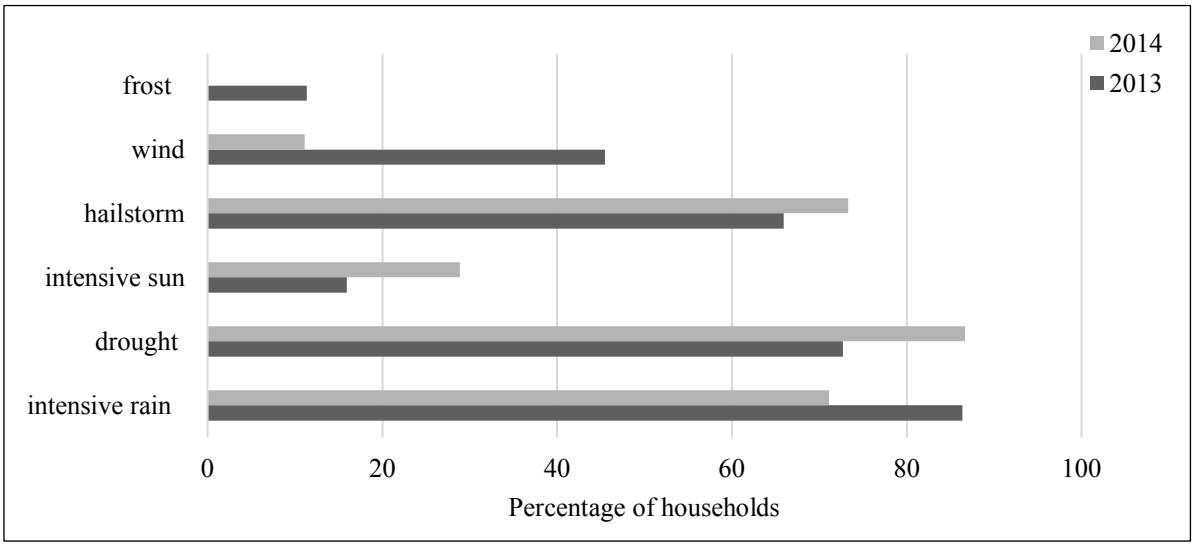


Figure 4.20: Percentage of household affected by extreme weather events during the research period; based on 64 household interviews.

Impacts and strategies to cope with intensive rainfall

Farmers reported the beginning of the rainy season as unpredictable. Similar as observed in the highlands case study, the intensity and duration of the rainy seasons are erratic. Instead of long seasons with little precipitation, farmers reported short but intensive events of precipitation. The consequence of this phenomenon is reflected in the percentages of households affected by floods, river floods, landslides and pest attacks (Figure 4.21).

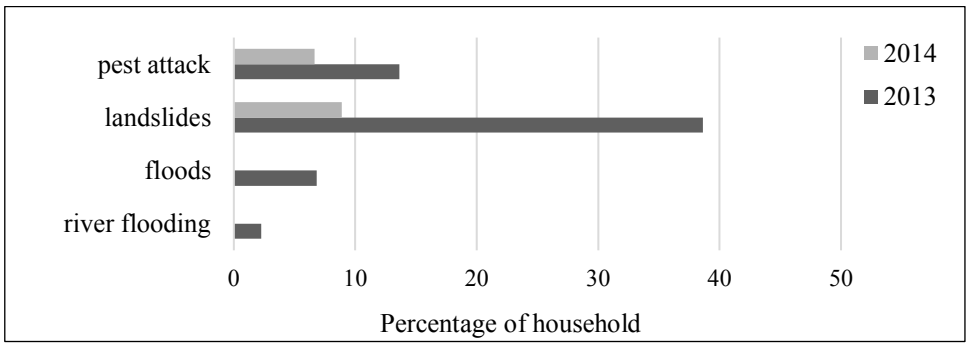


Figure 4.21: Percentage of households affected by the impact of intensive rainfall during the research period, based on 64 household interviews.

Farmers reported landslides as the main consequence of intensive rainfall. The deterioration of roads due to landslides leaves isolated local populations for several days. Landslides affecting shelter were less likely, but several houses were affected by land displacement from above. Finally, farmers have related the pest attacks mainly to the increase of rainfall. Standing water and the increase of temperature led to the right conditions for the spread of pests, mainly the fruit flies.

Households experienced losses in production followed by soil damage, infrastructure damage, no access to the market, livestock damage and health problems (Figure 4.22). The rainfall took away peach flowers, the most important economic crop for the area. Livestock damage was measured by the number of sick cattle as a result of increased moisture. Among infrastructure damage reported, the most common were moist walls and damage in the corrals. Some households were not able to take their agricultural production to the markets due to landslides in the rural roads. Finally, a few cases of health problems were reported, with a low incidence of colds due to moisture inside the house.

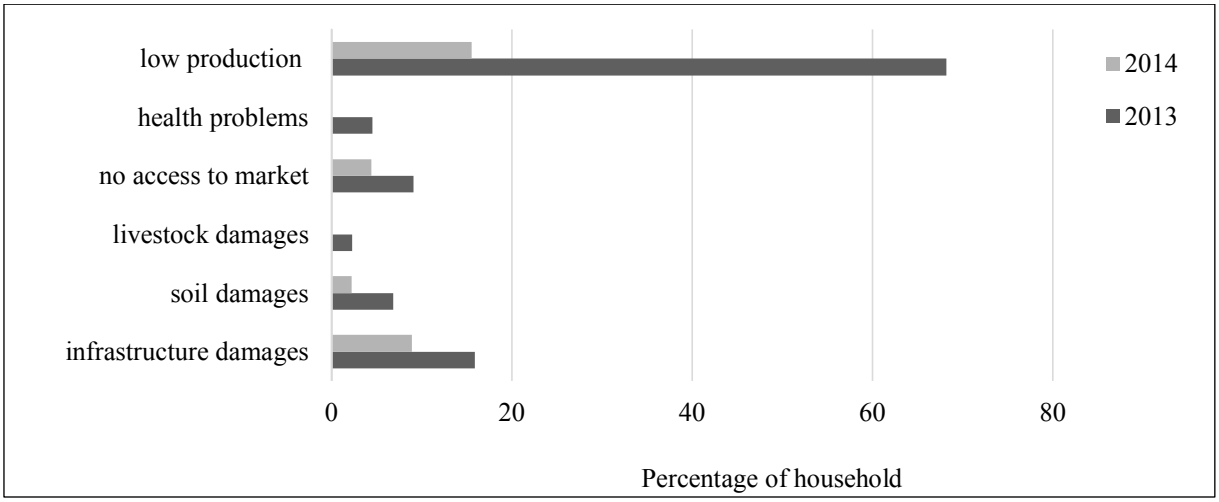


Figure 4.22: Damages of livelihood resources as a consequence of intensive rainfall in the inter-Andean valley based on the percentage of households affected. Information collected from 64 household interviews.

The strategies reported by farmers to increase the quality and quantity of agricultural production when intensive rainfall occurred relied on the traditional and modern knowledge of agricultural practices, such as the use of climatic indicators (described in detail section 5.1.2, table 5.1) and use of pesticides (Table 4.6).

Table 4.6: Strategies used by farmers to cope with event of intensive rainfall in the inter-Andean valley based on 64 interviews

Impact	Coping Strategy	2013 (% HH)	2014 (% HH)	Effect
Agricultural production	use of climatic indicators	47,72	33,33	Null
	use of traditional rituals	2,27	2,22	+
	digging of channels	6,81	0	Null
	use of pesticides	36,36	13,33	+
	use of homemade fly traps	2,27	2,22	+
	changes on production cycle/ harvesting	0	4,44	+
	crop rotation	0	8,88	+
	use of live barriers (Eucalyptus)	0	2,22	Null
	purchase of seeds	0	11,11	+
Infrastructure - No access to market	help from local government	2,27	2,22	+

Own research derivation based on household survey, where %HH = percentage of households

Despite the local concern on the impact of intensive rainfall among the local population, not many recommendations have been proposed by the households. Households from the inter-Andean valley mentioned that is more important the reinforcing of social organization, renewing seeds and access to climatic information (Figure 4.23).

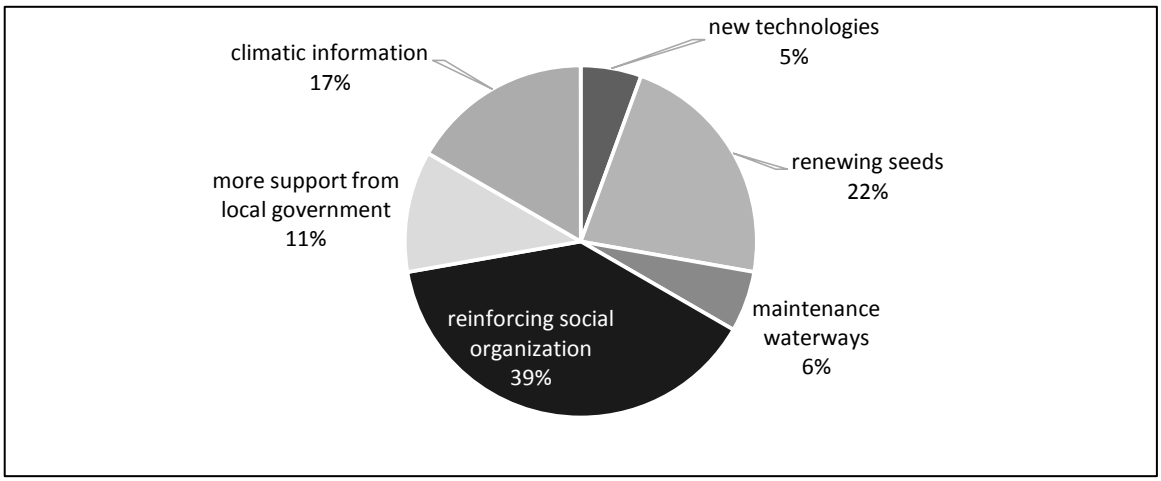


Figure 4.23: Local recommendation to cope with intensive rainfall event in the inter-Andean valley

Impacts and strategies to cope with prolonged drought

A total of 8 negative impacts has been identified as a consequence of the prolonged drought season (Figure 4.24), with most of the household having experienced agricultural losses. The prolonged drought season has affected the flowering of the peach, causing a massive yield reduction. Further on, not all members of the community have access to drinking water. Less than 10% of households reported the need to walk long distances to collect water from streams or rivers for cooking and drinking purposes. The health problems reported in this area were related to stomach diseases due to the lack of clean water for cooking.

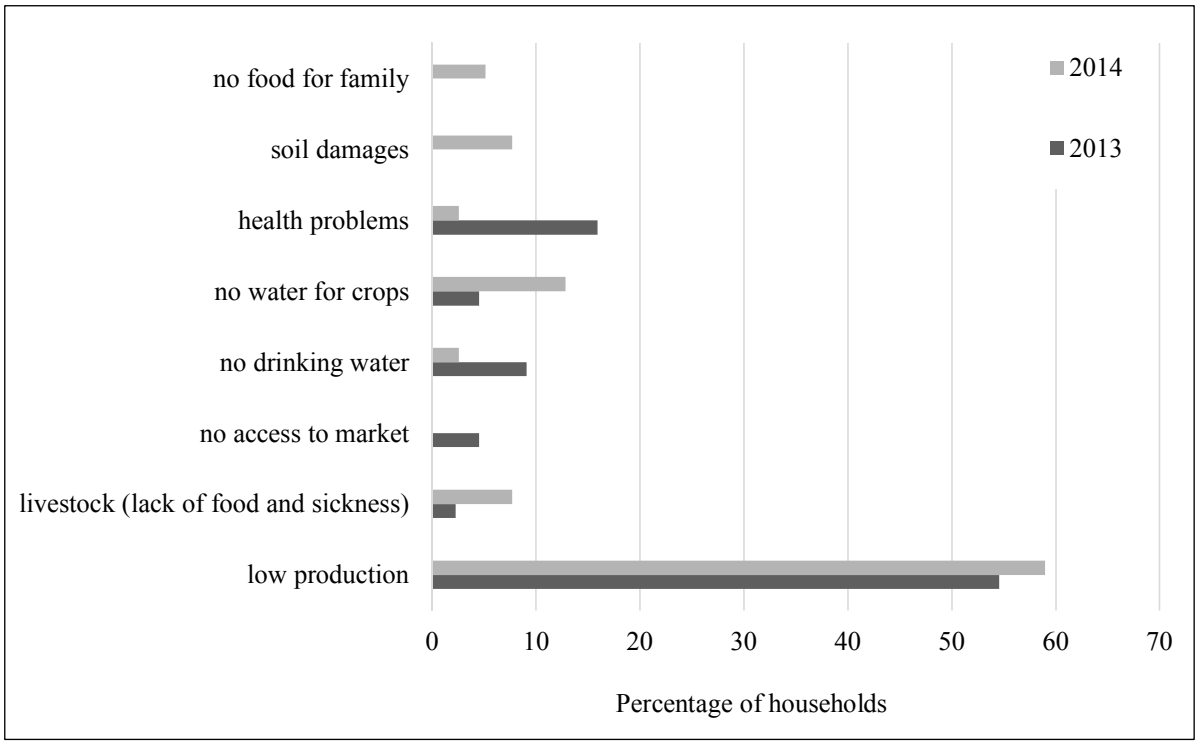


Figure 4.24: Percentage of households that have been impacted by prolonged droughts during the research period. Information based on 64 household interviews.

Registered coping strategies used by farmers to maintain agricultural production followed a prolonged drought period focused on food storage, an increase of labor, the performance of traditional rituals, soil conservation techniques and implementation of the irrigation system. Other strategies were: storage of food for animals, selling livestock before a drought period, diversification of products, transporting water in drums, canalizing the water, giving time to the land to rest and walking long distances with livestock looking for grassland (Table 4.7).

Table 4.7: Identification of strategies to cope with the impacts of prolonged droughts in the inter-Andean valley based on 64 households interviews.

Impact	Coping Strategy	2013 (% HH)	2014 (% HH)	Effect
livestock	food storage for cattle	2.27	0	+
	purchase food for cattle	0	13,33	+
no access to market - soil damages - low production	help from local government	2.27	2,22	+/-
	crop rotation/new area for cropping	2.27	6,67	+/-
	changes on production cycle/harvesting times	2.27	26,67	+
	soil conservation techniques	2.27	26,67	+
	use of traditional rituals	11.36	51,11	Null
	product diversification	0.00	6,67	+
	Increase of labor	70,45	62,22	+
no drinking water	bring water in drums	4,55	2,22	+
no water for crops	maintenance waterways	2,27	0,00	+
	use of irrigation system	40,91	37,78	+/-
health problems	use of sun protection	2,27	0,00	+
	decrease in working hours	4,55	2,22	-
no food for the family	food storage	52,27	75,56	+

Own research derivation based on household survey, where %HH = percentage of households

Farmers have highlighted the importance of access to water resources as the main strategy to cope with prolonged droughts. The implementation of a new irrigation system and the maintenance of the existing old water channels are the main recommendations to improve agricultural production (Figure 4.25). However, for the implementation of the irrigation system, the local government, social organization and NGOs have an important role in providing technical support and supervision, as well as materials and economic resources.

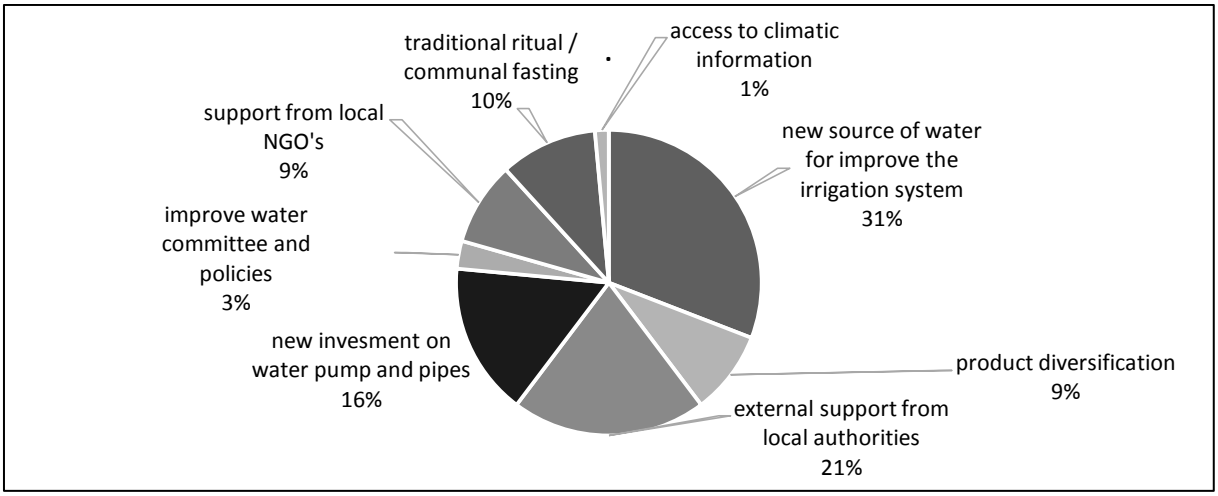


Figure 4.25: Local recommendations to cope with prolonged drought season in the inter-Andean valley.

Impacts and strategies to cope with hailstorm

The occurrence of hailstorms represents a threat for the production of peaches. After a hailstorm, the peach trees lost a significant number of flowers affecting the total production of more than 60% of the households and about 20% of households reported low quality and crop production (Figure 4.26).

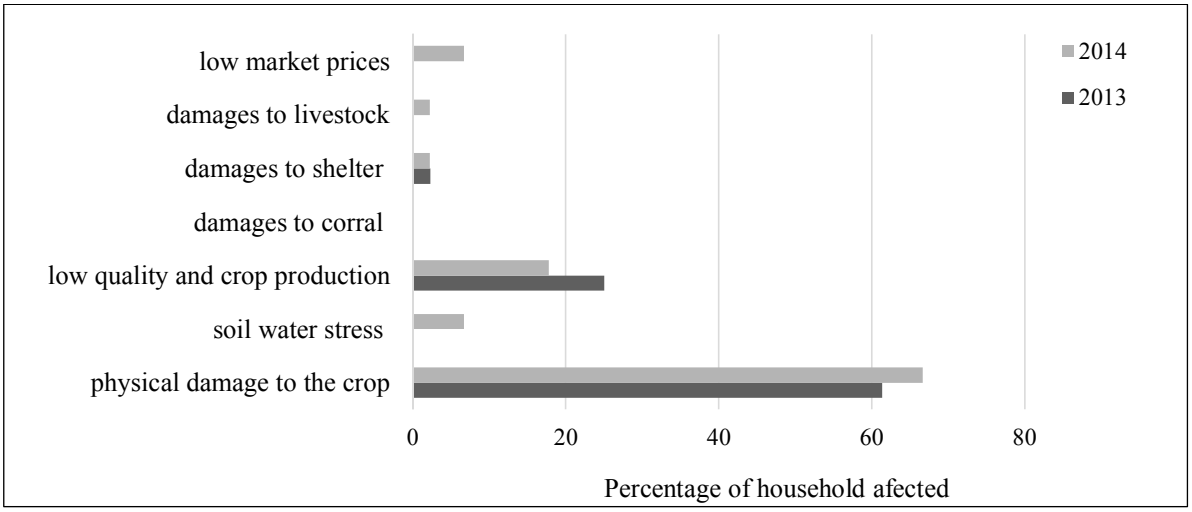


Figure 4.26: Percentage of households affected by hailstorms during the research period in the inter-Andean valley, based on 64 household interviews.

The identified coping strategies have shown the importance to prevent the hailstorm by applying local techniques such as the use of salt, firecracker, and dynamite. The use of firecrackers is the most popular technique and has a positive impact on avoiding the

occurrence of hailstorm. Few farmers relied on the performance of traditional rituals to prevent yield reduction, but it has no impact on the production (Table 4.8).

Table 4.8: Identification of coping strategies to prevent the impact of hailstorms and agricultural losses.

Impact	Coping strategies	2013	2014	Effect
crop damages - soil damages - yield reduction - animal damages	use of salt	0	2,22	null
	stoked	2,27	2,22	+
	firecracker	65,90	71,11	++
	dynamite	0	2,2	-
	use of traditional rituals	2,27	6,66	null
	crop rotation	2,27	2,22	null
infrastructure damages	corral reinforcement	0	4,44	+

Own research derivation based on 64 interviews

With the participation of the farmers, four recommendations have been identified to avoid damages due to hailstorm (Figure 4.27). The community work and the reinforcement of social organization were recommendations for agreements on the use of firecrackers synchronously by all community members in coordination with local authorities. The use of greenhouse was a recommendation to avoid physical damages in the crops and finally, the performance of traditional rituals was a recommendation to prevent the hailstorm.

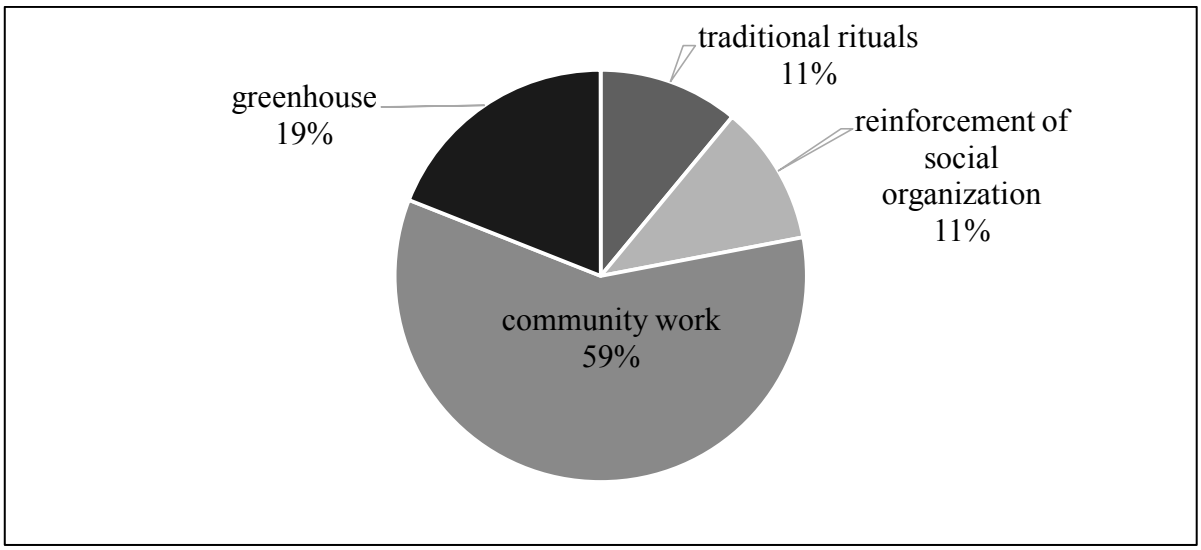


Figure 4.27: Local recommendations to cope with hailstorm in the inter-Andean valley, based on 64 household interviews

Impacts of frost events

The occurrence of frost is not very common. Less than 5% of the household having reported damages due to frost events; these farmers had potato crops in the upper part of the community (Figure 4.28). No local strategies were identified to secure crop production after a strong event of frost.

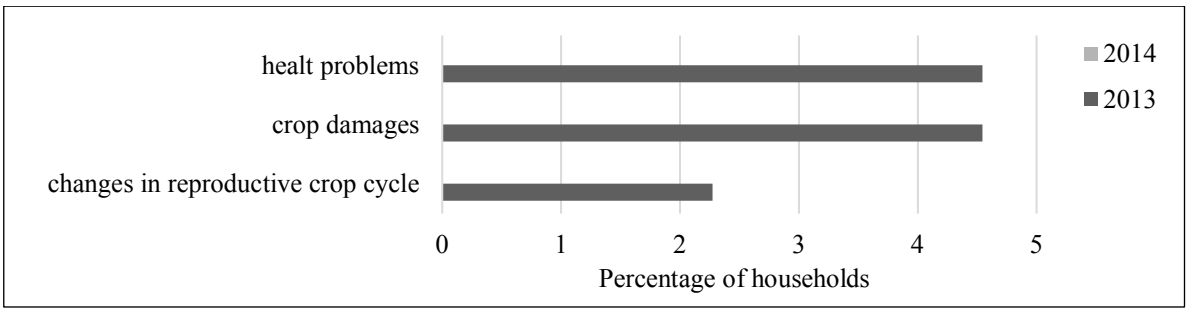


Figure 4.28: Percentage of households affected by frost events based on 64 household interviews.

Impacts and strategies to cope with strong wind

A total of 34% of the households in the valley were affected by the occurrence of strong winds. The main problem was the reduction of the peach production because the wind blew away each flower. The damage was not quantified, but local farmers mentioned that due to the strong wind, the production of peach was reduced by more than 50% compared to the previous year. At the same time, farmers reported that wind was so strong that it took off and destroyed the roofs of 20 houses, 45% of households. Most of the given answers declared that there was nothing they could do. One household mentioned that the performance of traditional rituals could be the solution for stopping the wind, but that the reinforcement of infrastructure was also necessary.

5. LIVELIHOOD ADAPTATION STRATEGIES BASED ON CULTURAL KNOWLEDGE

5.1 Description of the existing traditional knowledge

5.1.1 Cultural identity and performance of rituality

The lifestyle of families in both case studies is the example for the diversification of traditional ecological knowledge. Over the years, rural communities supported their activities on livelihood adaptation strategies to cope with changing socio-economic conditions and climate variability. The traditional ecological knowledge has been complemented by modern techniques and technologies commensurate to the local reality and intimately related to the agricultural practices. The evolution of this knowledge has allowed the communities to maintain the lifestyle as farmers in their current location.

Transfer of knowledge in the communities is made verbally from one generation to the next. The number of households that have learned agricultural practices from the elders in the family was 87% in the highlands and 94% in the inter-Andean valley. This percentage has been reduced for the new generation, 35% households from the highlands and 23% households from the inter-Andean valley were not able to transfer agricultural knowledge to the young generation. As observed during the research, young people in the communities tend to adopt customs of the city; leaving aside the traditional clothing, low knowledge of local language and tend to use words in English and with the higher aspiration of further education and life in the city rather than in the communities.

Independently of the case study, cultural beliefs of the Aymara people are rooted in pantheistic worship, which means they believe in different Gods or divinities such as *Inti*, *Pachamama*, and *Achachilas* (respectively translated from the Aymara language: Father Sun, Mother Earth, and Grandparents Mountains). The *Pachamama* or Mother Earth is the goddess related to production. Despite the Catholic faith, they continue worshiping *Pachamama* as they did in ancient times. There are many ceremonies in her honor, during sowing and harvesting times. The main tribute is observed during the month of August. The performance of ritual in the communities is seen as a strategy to cope with extreme weather events. Households mentioned the importance of these rituals for calling the rain after a prolonged

period of drought and to prevent hailstorms. *"We are suffering the consequences of droughts because our authorities have forgotten our traditions and they are lazy to perform the rituals for the Pachamama"* (Victoria Laruta - 42 years old - Santiago de Okola 2014).

The number of households that perform traditional rituals and rely on their cultural beliefs as strategy to secure food production was less than 38% in the highlands (median = 0.24; min = 0; max = 1) and less than 43% in the inter-Andean valley (median = 0.20; min = 0: max = 0.75). Previous research (Gille et al. 2013, Ziche and Rist 2001), associate the loss of traditional practices with the arrival of evangelical religion. People have abandoned these practices because of their association with "pagan" beliefs. Despite the inhabitants of both case studies are Aymara, different rituals have been recorded. In the highlands case study, one of the most developed and known ritual was the so called "*Challa*". Local people mentioned that the meaning of this ritual is to thank the "*Pachamama*" and to ask permission for the use of natural resources. Furthermore, specific ceremonies are performed to cope with climatic conditions such as: welcoming the rain, to avoid or dismiss drought, and for calming strong winds. Local testimonies mentioned that the loss of ritual practices and cultural beliefs of the young generation is related to the arrival of different protestant church groups, and also the lack of interest of young people.

In the inter-Andean valley, the "*Ayuno*" or fasting was recorded as a ritual that involves all members of the community and consists of the capture of water from three different streams. For that, three community members selected by the authorities are sent to different locations to collect water from the main stream, and once they are back in the community the collected water must be dispensed over the main river and all community members must start one week of fasting. The concept behind this ritual is to bring water for the crops. During the last year of research, community members with the leader on the head were organizing themselves to perform this ritual, as a strategy to cope with the impacts of drought.

5.1.2 Weather forecasting

The use of indicators based on traditional ecological knowledge is intimately related weather forecasting. Independently of the case study, farmers have used observations of natural phenomena such as stars, winds, plants, and animals as part of their strategies to deal with weather-related risk. In the highlands 48 %, and in the inter-Andean valley 40 % of the

households rely on this knowledge for the development of the crops, it supports the farmers decided when and where to place a crop and what variety should be used. Three groups of weather indicators have been identified: zoo-indicators, phyto-indicators and atmospheric and astronomic indicators (Table 5.1).

Table 5.1: Traditional forecasting techniques identified during the survey based on 125 household interviews.

	Highlands	**Inter-Andean valley**
Zoo-indicators	• Fox howling announces the planting time and place. • The arrival of small birds announces the change of season. • If the cattle cry, rain will arrive in three days' time. • *"chiwanku"* (local name of a bird) fly before the rain comes. • Farmers start planting after "*chiwanco*" sings. • Small shallow - small rain; big shallow - electric storm. • Singing toads attract rain. • Flock of birds announces the arrival of a hailstorm.	• Flight of swallows announces rain. • Agglomeration of ants is a moisture indicator. • Partridge walks when it will rain. • Eagle cry stops the rain. • Location of birds nest close to the ground is an indicator of a dry year, and when the nest is at a higher elevation, a lot of rain will come.
Phyto-indicators	The blooming of some species is a moisture indicator.	

Continuation…

	Highlands	Inter-Andean valley
Atmospheric and astronomic indicators	• The observation of the brightness of the stars and the color of the moon determine the future availability of water, thereby guiding the annual agricultural cycle. • The position and color of the moon indicate the arrival of rain and its intensity.	• If the clouds come from the west, then the rain will come. • Harvesting time needs to be during a full moon for better products. • Whenever the moon is yellow a lot of rain will come. • Rainbow and the sun mean good day to work and plant.

Own research derivation based on household survey (61 interviews in the highlands and 64 interviews in the inter-Andean valley.

The use of indicators on weather forecasting has the potential to reduce the impact of climate variability and change (Gilles et. al. 2013). Independent of the case study, survey data indicates that almost half of the population does not rely on the use of indicators in weather forecasting. There was a consensus among the population that the use of these indicators is no longer working. Two explanations were given: 1) the young people do not know these indicators, and 2) weather conditions change drastically from one year to another making the observation and understanding of new conditions difficult. Gilles et al. (2013) conducted research in the highlands that indicates that the decline in the use of indicators has occurred in less than a decade, and is related to the use of chemical fertilizers. When farmers have the resources to obtain more fertilizers, the use of indicators declines even more.

As indicated by Gilles et al. (2013), previous research has validated the predictive value of astronomical observations for predicting wet and dry years and for predicting potato production. Validating other indicators under the current climatic conditions became a necessity as this technique can lead to agricultural production under the best soil and environmental conditions and reduce losses due to extreme weather events. Weather forecast knowledge based on observations of wildlife behavior as well as atmospheric and astronomic indicators should be valued as it contains cultural knowledge accumulated for centuries (Matijasevic 2013).

5.1.3 Mobility

This research focuses attention on barter-trade practices, access to the market, and migration, which are considered mobility strategies that support the well-being of families. These strategies are rooted in the Andean traditions in which people have continued a way of life which has effectively withstood the pressures of constant natural and societal changes over the time. The most important strategy consisted of maintaining the traditional system of land use which involves the vertical exploitation of numerous ecological zones, known as the "simultaneous control of ecological levels system". This system provides access to a wide range of natural resources including products from humid lowlands, grazing land on the high *puna*, valleys, and occasionally from the Pacific Ocean. Today, this practice has been partially replaced by different means of trade, for example, the markets.

Despite the high rates of migration in the Andes of Bolivia, migration was and still is a strategy that provided families access to markets and a wide range of economic opportunities. Currently, due a complex set of factors related to changes in the production system and livelihood strategies influenced by labor and commodity markets, migration has become a livelihood strategy, reducing available farm labor (Gilles et al. 2013).

Barter-trade practices: "Trueque"

The barter-trade practice or *trueque* (in the Aymara language) is the traditional way to interchange products between the communities. This traditional practice allows the families to access products that they do not produce, promoting food security of the household. Based on data survey, 75% of the households in the inter-Andean valley performed *trueque* in community festivities, local markets, and weekly local fairs. During these activities, people from various communities come together in one place, and they have the opportunity to interchange their own products with products from other communities. Furthermore, some families perform *trueque* with communities in the highlands. In this case, the ration is one box of peach (or other fruit) for one sack of potato.

Usually, this interchange of products happens between relatives or close friends of the family, for example, the godparents. In the case of highlands, 49 % of the households performed *trueque* during local fairs or with other households living in the community. Throughout *trueque* during local fairs, families have access to a vast variety of seeds and meat. The units

for the interchange are established between traders. *Trueque* between families living in the community is based on local products and occurs mostly between relatives. Farmers have access to new pools of seeds by participating in local markets, trading with neighboring communities or purchasing. Farmers look for new varieties that can support them to secure food production and which can be more resistant to extreme weather events.

The access to market

Independent of the case study, access to the market is determined by distance. The majority of the population, if not all, have access to local markets or local fairs. Commonly, every region in the rural areas performs a local fair once a week. The local fairs are a social space in which people have the opportunity to access a higher variety of resources. The size of the fairs is directly related to the location. In the case of the highlands, most of the families attend a local fair that takes place once a week in the neighboring community, located ten minutes away by car from the community. Moreover, 57% of households declared to have access markets in the cities of La Paz and El Alto (3 hours of travel on average).

In the case of the inter-Andean valley, the main fair takes place every Thursday in Inquisivi, the capital of the municipality. Data survey shows that all the families from the communities attend the fair at least once a month. Moreover, 60.4% of households from the valley travel longer distance to access markets in the cities of La Paz and El Alto (7 hours of travel on average). Access to markets in the city provides the families the opportunity to sell their products at better prices and to access a higher diversity of resources for the household.

Migration

The migration of the Aymara people is not a recent phenomenon – it has its roots in ancient cultural traditions. However, today the global changes are pushing a large number of people from rural areas to urban centers. Moreover, yields in quantity and quality have gradually diminished, making agricultural production and the stay of the families in the rural areas unsustainable. First, temporary migration occurred, which then became permanent, in search for different opportunities (Matijasevic 2013). Moreover, access to information, improvement of means of transportation and roads contributed to people, especially the youth, adopting cultural behavior adopted from urban environment.

In the case of the highlands, 55.2% of household members have migrated permanently out of the community. Based on survey data, the people of the highlands that live permanently in the community are old (household head: 62 years old). Most of the young population (between 15 and 45 years old) have migrated to the cities (as described in Chapter 4). Additionally, during the dry season, the men of the household participated in mining activities outside the community or moved to the cities of La Paz and El Alto for temporary wage work in construction or transportation.

In the inter-Andean valley, just 28% of household members have migrated permanently outside the community. Based on data survey, men and women travel for short periods of time to neighboring communities or to the main capital in search of temporary sources of income whenever needed. Here, households contain on average 3.9 people, and the average age of the household head is 51.8 years old. Consequently, these data suggest that the population in this region is younger and more labor is available.

5.1.4 Social-pooling

The strategy of social-pooling refers to relationship that actors have in the community (see Table 3.6). When the relationship occurred between families or another community member, they follow the traditional economic model of organization that is based on long-term reciprocity. This model regulates the provision of goods and services among families. This traditional way of labor interchange occurred in three different ways: *ayni, minka* and *waki*.

The ayni is a practice performed daily among members of the community, including relatives and neighbors. It refers to a mutual cooperation mostly for private projects. In this practice, the host family reciprocates the aid in the future and the family that supports it is provided with food and drink. This practice represents a way of giving loans for crop products, livestock, and other goods.

The minka is a kind of social work that involves a larger number of community members, can be applied to communities or larger territories and contributes for instance to the construction of schools, roads, and/or water systems. Also, members of the community contribute to crop production to the elderly, orphans or disabled people. The work is remunerated with cash or other goods and returning the work with the same number of hours.

The waki is a practice in which one household contributes with land and the other with seeds and the labor and production are split equally.

5.1.5 Storage and processing food

The knowledge of techniques for storing and processing food is used in both regions. In the highlands 72 % of the households practice processing and transformation of food. Families have developed great knowledge on the production, process and storage of roots and tubers, such as potato (*Solanum sp*.) and oca (*Oxalis tuberosa*). Through a complex process of freeze-drying and dehydration the *chuño, tunta* (dry potato) and *khaya* (dry oca) are processed. These products can be stored for several years and bring nutrition support for the families as well as an alternative income source when the families decide to sell or barter. The storage of fresh products in the highlands requires simple infrastructure made with dry grass or straw, in some case also with the use of lime and other chemical products. Also, families store up their products using large, thick plastic bags. Few families have mentioned that they store food for livestock for the dry season. 95 % of the households storage food for the dry season, the storage of seeds for farmers is equivalent to have money in the bank. Two techniques of storage have been identified. For the potato, farmers build a small tent made of dry grass very compact and storage the potatoes inside. Other products are storage in sacks well close in a dark room inside the shelter.

In the case of inter-Andean valley, 70 % of the families, at the end of the harvesting season, process "*quisa"* (dry peach) by dehydrating the fruit. "*Quisa*" represents an important alternative income source and prevents the loss of production. The fresh products are stored using chemical products; other families transport the products to highlands for storage purpose. Finally, families do not have the need to store food for livestock because it is possible that the animals find food all year round.

5.1.6 Selection of agricultural practices

Selection of agricultural practices refers to the use of knowledge and techniques to improve crop production. Here, two sets of strategies were selected: soil management techniques and management of agrobiodiversity. The first case refers to the access of modern techniques, like irrigation systems, use of tractors or other technologies, and the use of traditional ecological knowledge on crop production and soil management. In the second case, the management of

agrobiodiversity, in the highlands the knowledge on agrobiodiversity was concentrated on few species (average = 5.48 species) but a large number of varieties (average = 12.5 varieties). On the contrary, in the inter-Andean valley, the average number of crops and varieties was 5.68 and 6.75 respectively. This phenomenon can be explained by the fact that in the highlands the environmental conditions do not allow the diversification of many crops, therefore by diversifying the varieties the households can secure their production. In the inter-Andean valley, households can produce different crops all year-round.

In both case studies, these techniques are recognized as coping strategies to secure food production. Soil conservation techniques identified were related to crop rotation systems, live barriers, and changes in production cycle maintenance or water channels. Its implementation requires time, land and labor. Currently, these techniques are used for a small percentage of households (Table 5.2) and can be related to the lack of land and labor. Therefore, farmers rely more on the use of fertilizers and contracting labor (or accessing *minka* and *ayni*). Moreover, farmers in cooperation with stakeholders are establishing new irrigation systems.

5.2 Cultural strategies to support crop production

The development of an index to assess the impact of cultural strategies in crop production focuses the attention on those strategies with higher impact. Here, the quantitative analysis of traditional ecological knowledge is measures base on the selection of seven major categories of cultural knowledge: cultural identity, weather forecasting, social-pooling, mobility, storage of agricultural products, selection of agricultural practices and economic diversification (Table 5.2).

Table 5.2: Identification of variables for the assessment of cultural strategies that support the agricultural production, and the percentage of households that rely on these strategies

Major category	Sub-category	Highland (% of households)	Inter - Andean valley (% of households)
Cultural identity	transfer of knowledge	35.0	23.0
	religious group	5.1	25
	practice of rituals	48.7	40.9
	use of medicinal plants	74.4	79.5
Forecasting and TKE	zoo - indicators	20.5	34.1
	phyto - indicators	15.4	4.5
	astronomic - indicators	30.8	6.8
	atmospheric - indicators	30.8	22.7
Mobility	migration	63.6	28.2
	local trueque	7.7	36.4
	regional trueque	2.6	27.3
	trueque with neighbors	38.5	13.6
	local market	64.1	59.1
	regional market	15.4	27.3
	city market	20.5	11.4
Economic diversification	crop production	100	97.7
	eucalyptus plantation	15.4	40.9
	natural resources related activities	38.5	20.5
	out-farm activities	33.3	40.9
	livestock production	76.9	75
	off-farm activities	48.7	45.5
	remittance	53.8	36.4
Storage and transformation	water storage	12.8	22.7
	drinking water	92.3	95.5
	seed storage	100	81.8
	food storage	94.9	52.3
	food storage for livestock	10.3	0
	food processing and transformation	71.8	70.5

Continuation…

Major category	Sub-category	Highland (% of households)	Inter - Andean valley (% of households)
Social -pooling	participation in *minka*	41	70.5
	participation in *ayni*	41	65.9
	participation in NGOs activities	35.9	52.3
	participation in local government activities	12.8	27.3
	local authority	79.5	22.7
	participation in local syndicate	28.2	11.4
	participation in local association	30.8	13.6
	family relationships	92.3	93.2
	knowledge interchange with members of the community	5.1	4.5
	participation of training programs	2.6	4.5
Selection of agricultural practices	crop association	87.2	81.8
	organic fertilizer	76.9	68.2
	chemical fertilizer	71.8	36.4
	use of tractors	69.2	18.2
	use of irrigation system	12.8	63.6
	use of firecrackers	17.9	63.6
	reinforcement of infrastructure	2.6	2.3
	dig water channels	12.8	6.8
	changing production cycle and harvesting time	5.1	4.5
	reduction of working hours	0	2.3
	sun protection	0	2.3
	crop rotation	89.7	86.4
	fallow land	71.8	79.5

Research own derivation based on household survey

5.2.1 Highlands case study

In the highlands, the tree regression analysis identified two major categories of cultural knowledge significant (Figure 5.1). Economic diversification (in 30.35%) and mobility (in

9.89 %) were the cultural strategies that have contributed significantly to crop production. A similar pattern is explained by Valdivia et al. (2013) who point out that the connection between agricultural and non-agricultural activities is a diversification strategy that supports buffering the climatic variability. The income from activities not depending on land is an important alternative for households in the highlands, especially during drought season. But the negative consequences of increasing non-agricultural activities or off-farm employment is the declining of available labor on the farm. Moreover, off-farm activities pushed many farmers to temporarily migration. On the other side, strategies based on mobility provide a different alternative to access a bigger range of resources important to securing the well-being of the households.

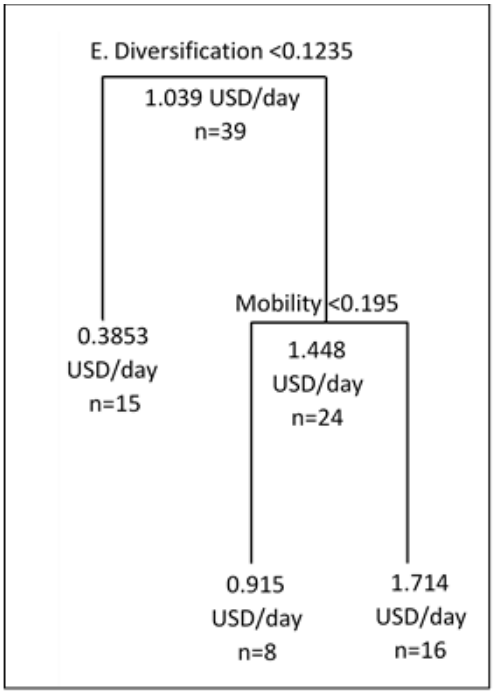


Figure 5.1: Cultural strategies that support crop production in the highlands. The assessment has been carried out using tree regression analysis based on 39 household interviews.

Generally, communities in the highlands are well known for their traditional knowledge on weather forecasting and cultural beliefs, the development of the model shows no significant impact of these strategies on crop production. The traditional knowledge is learned from the experience of living in direct contact with the environment, but the current context of

migration, especially young people to urban areas and the dominance of formal education in the schools, threatens the survival of these cultural traditions (Armelin 2011). The fact that young people are going to school and then have off-farm employment mostly limits their participation in agriculture. So even though there is an awareness that the knowledge is in the hands of the old people, they do not have the opportunity to learn from them (Gilles et al. 2013).

Additionally, farmers cannot rely entirely on climatic indicators because the behavior of the indicators is also changing, for example, the location and the season of birds nest are different. Therefore, the integration between modern science and traditional knowledge is essential for the elaboration of adaptation strategies, for example, the integration of early warning system (FAO 2011). Moreover, the current national policy in Bolivia since 2006 promotes the use and conservation of indigenous knowledge, however, families in the highlands agree that the use of knowledge on weather forecasting and performance of rituals is declining, a similar situation has been registered in near areas (Gilles et al. 2013).

5.2.2 Inter-Andean valley case study

In the inter-Andean valley, the tree regression analysis highlighted the contribution of three strategies on crop production: Social-pooling, mobility, and selection of agricultural practices (Figure 5.2).

1) Social-pooling contributed 41.5% to crop production. That means that relationships among households and other stakeholders play a key role in agriculture. Social-pooling is also seen as the integration of households in a social network that brings the household access to different resources and knowledge that contributes significantly to crop production (as explained further in Chapter 7).

2) The second cultural strategy that contributes to crop production was mobility with 10.6%. Mobility is not a new strategy, used by the Andean people as a mechanism to access different resources and evolving through the years. For instance, migration today is an individual or familial process, related not only to lack of resources but also to new ways of thinking that guide them to look for a different style of life. Nevertheless, the relationship between the migrant and the local family remains strong and supports the local family to access different

resources. Unfortunately, the present model does not make a deep assessment of migration patterns, instead just focus the attention of the percentage of household members living permanently outside the community.

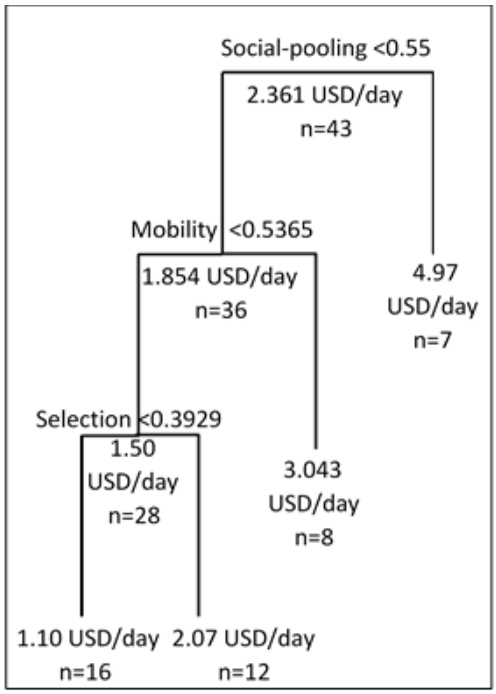


Figure 5.2: Cultural strategies that support crop production in the inter-Andean valley. The assessment has been carried out using tree regression analysis based on 43 household interviews.

3) Finally, the selection of agricultural practices with 4.67% influences the crop production. This last strategy has great potential in the coming years as the main driver of success with the implementation of a new irrigation system in the area, which is in its early stage and more families will start taking part in it. Agricultural practices were focused on diversification of products, use of pesticides and pest management (homemade fly traps), purchase of seeds, and implementation of irrigation systems. Most of these techniques have been developed in cooperation with local institutions that have been working in the area for several years. Therefore, a small percentage of households rely on these practices (see details in Table 5.2).

6. SOCIO-ECONOMIC STRATEGIES

6.1 Diversification of socio-economic strategies

6.1.1 Principal income sources and economic activities

Households pursue a wide range of economic activities and income sources to secure their livelihood. A total of 15 different sources of household incomes has been recorded including farming, carpentry, weaving, local handicraft, transportation, trade, daily labor, collection of medicinal plants, fishing, services, tourism, mining, honey production, and remittances. Moreover, these sources of income were related to the characteristics of the agro-ecological region and availability of resources in the household. For instance, in the highlands, besides agriculture, typical activities developed were: fishing; handcrafted knitting, and tourism. The number of income sources per household was between two and six, with an average of four. For the inter-Andean valley, besides farming, the typical sources were: collecting and selling wild medicinal plants, handicraft basket-weaving, honey production, and day labor in other farms. The number of income source per household was between two and six, with an average of four. The total of income sources has been clustered in seven categories (Table 3.7): crop production, livestock production, eucalyptus plantation, natural resources-related activities, out-farms (for example: daily labor, agro-tourism, honey production), off-farms (for example: wage work, mining, and trade), and remittance and bonds (Figure 6.1).

Figure 6.1: Diversification of economic activities in the communities a) crop production, b) fishing and c) handicraft production.

The household income is related to the agricultural calendar of each ecoregion (Table 6.1). In the highlands, the agricultural year begins in August with the preparation of the soil, from September to December planting season takes place in separate periods, and the harvesting

starts from February to March depending on the crop. Parallel, the recollection of medicinal plants takes place as the abundance of vegetation during this season is greater. Agriculture and collecting medicinal plants in the highlands depend directly on the rainy season. Outside this season, the dry condition of the environment is not suitable for vegetation or crop-growing.

Table 6.1: Calendar of economic activities developed by households in the highlands based on 61 household interviews during 2013.

	J	F	M	A	M	J	J	A	S	O	N	D
Crops												
Livestock												
Eucalyptus												
Nat.res.act. (*)												
Out-farm												
Off-farm												
Remittance												

Own research derivation based on group discussion and household surveys; where dark gray = intensive activity, and light gray = non-intensive activity. (*) Nat.res.act. = Natural resources related activities (see table 3.7; section 3.3.3).

However, during the dry season farmers prepare food products for storage by applying different techniques, e.g. elaboration of "*chuño*" by dehydrating potatoes, as described above. In this season, livestock is reduced; most of the farmers sell some of their animals as the amount of grass is not enough. The income opportunities that do not depend on the season are mainly out-farm activities, described below:

- ***Harvesting of eucalyptus*** is an opportunistic activity related to household needs. Therefore, it happens occasionally at any time of the year.

- ***Fishing*** is a traditional activity of the population settled along the banks of Titicaca Lake and represents an important aspect of the economy of the people. This activity is seasonal depending mainly on the abundance of the fish that varies from year to year. Initially, it was based on native species and later on a variety of native and introduced species. Fishermen report the amount of fish to be unpredictable and the market price tends to

decrease dramatically when resource abundance increases and vice versa. The variation of the price is between 0.70 USD/10 kg to 41 USD/10 kg. The reduction of this resource is brought about by threats from the pollution from big urban areas around the lake and mining activities. Fishermen need to have a significant budget at the beginning of the fishing season, between 1000 USD to 1500 USD, to be able to purchase new nets; boat maintenance and other fishing equipment (see more detail section 7.1.9).

- ***Elaboration of handicraft*** (hand-knit blanket) is an outdoor activity developed by women in the community, it depends basically on the time available and weather conditions. Women set up their looms in their own backyard, and one hand-knit blanket can take between 5-15 weeks before is ready depending on the size and design. It can be sold for 10 USD to 50 USD.

- ***Agro-tourism activities*** are developed and implemented in the area by the Integral Tourism Association of Santiago de Okola (ASITURSO). This association is integrated by members of the community. Households that provide this service host between 10 and 20 tourists every year, mainly in high season from June to August for international tourists (see more detail 7.1.8).

- ***Off-farm*** activities increase during the dry season and depend on the number of persons in the household able to work, working knowledge and skills, age, health condition and resources available. Off-farm activities reported in the area were: mining, wage work, trade and provision of services (transportation and construction).

In the case of the inter-Andean valley, agricultural activities take place year-round due to the friendly climatic conditions. However, the principal economic crop “peaches” demands more labor during the rainy season, especially in the harvesting time, January and February. After this season, many other crops are developed mainly for subsistence. Livestock raising is a constant activity throughout the year. Cows, pigs, and chickens are the most common livestock but the number of animals differs from one household to the other. Harvesting of eucalyptus can be performed any time of the year and is usually related to market opportunities. Nevertheless, farmers avoid this activity during the rainy season due to the risk of landslides, as the plantation are located on steep slopes. Collecting medicinal and

ornamental plants is related to traditional festivities, e.g. Easter and Christmas, when the demand for these plants is higher. Out-farm activities are performed any time of the year, these activities are related to the time available of the farmer and the need of an additional source of income. Hence, the farmers work as daily labor for other farms in the same community or in neighboring villages. Finally, off-farm activities are performed year-round at least for a household member; off-farm activities are mainly focused on mining in neighbor communities, construction, and trade (Table 6.2).

Table 6.2: Calendar of economic activities developed by households in the inter-Andean valley based on 64 household interviews during 2013.

	J	F	M	A	M	J	J	A	S	O	N	D
Crops												
Livestock												
Eucalyptus												
Nat.res.act. (*)												
Out-farm												
Off-farm												
Remittance												

Own research derivation based on group discussion and household surveys; where dark gray = intensive activity, and light gray = non-intensive activity. (*) Nat.res.act. = Natural resources related activities (see table 3.7; section 3.3.3).

The distribution of income among the seven categories showed that in both case studies off-farm and crop production were the source that contributed the most to the total income of the households (Table 6.3). In the highlands, the results showed that off-farm activities contributed the most to the total income. The low income from crop production, particularly during the year of research, was related to the significant losses of crop production due to the extreme weather events (see detail in section 4.1.5). In the inter-Andean valley, crop production contributed the most to the total income followed by off-farm activities. In addition, out-farm activities contribute 10 percent to the total income mainly due to the daily labor of household members in other farms (Table 6.3).

Table 6.3: Income distribution for the highlands (n=39) and inter-Andean valley (n= 44).

Income source	Highlands		inter-Andean Valley	
	USD/day	%	USD/day	%
Eucalyptus plantation	0,04	0,64	0,18	3,39
Remittance	0,09	1,47	0,08	1,39
Livestock	0,19	3,28	0,08	1,55
Out-farm	0,36	6,18	0,58	**10,60**
Nat. resources related act.	0,56	**9,62**	0,03	0,53
Crop production	1,04	**17,97**	2,36	**43,51**
Off-farm	3,52	**60,84**	2,12	**39,02**
TOTAL	**5,80**	**100**	**5,43**	**100**

Research own derivation based on Table 3.7; Section 3.4.3

There is a rapidly growing body of literature on economic diversification which indicates that off-farm might become of considerable importance to livelihood strategies, especially when the impacts of climate change represent damages to crop production (Fang et al. 2014, Boillat and Berkes 2013). In addition, off-farm earnings represent an essential strategy to maintaining a viable farm that requires purchased inputs or that cannot generate enough cash income to satisfy the household's cash requirements (Barrett et al. 2001). Several authors (Fang et al. 2014, Soltani et al. 2012, Ansoms and McKay 2010) highlight the role of off-farm activities as a livelihood strategy in breaking the vicious cycle of poverty and bringing new opportunities for poor households. But also, as described above, off-farm activities reduce labor in the communities and competes with the conservation of traditional ecological knowledge related to sustainable agricultural practices. Moreover, Off-farm activities are negatively associated with the maintenance of biodiversity (Gilles et al. 2013).

6.1.2 Index of economic diversification

The data gathered in the assessment of economic diversification suggests that the socio-economic and environmental characteristic of a particular agro-ecological region determined the development of a particular strategy of economic diversification. The available evidence shows that higher economic diversification in the inter-Andean valley results in better income for the households (Figure 6.2). As cited by Barrett et al. (2001) economic diversification is a strategy in which many households reduce risk to social and environmental changing conditions. Moreover, diversification is a self-insurance strategy in which people exchange

some foregone expected earnings for reduced income variability achieved by selecting a portfolio of assets and activities that have a low or negative correlation of income (Barrett et al. 2001). Therefore, the more diverse the income portfolio, the better off the rural household is and the more opportunities to cope with and adapt to climate change there are (Ellis 1999). Families explore for economic diversification depending on several factors: seasonality, risk strategy, labor market, asset strategy or as a coping behavior for adaptation. For example, seeking out seasonal wage-earning opportunities, education of the children, purchase of fertilizers and other agricultural inputs or invest in equipment for agriculture (Ellis 2000). Economic diversification is not always positive, also implies a reduction of labor for agricultural production or bringing agricultural production as a secondary activity, enough for self-consumption (Matijasevic 2013).

Data survey suggests that farmers invest the income generated from different out-farm and off-farm activities in agriculture in order to secure food production. According to Ellis (1999), poor migrants from remote areas are less likely to re-invest urban earnings in agriculture while better off migrants from nearby areas are more likely to do so.

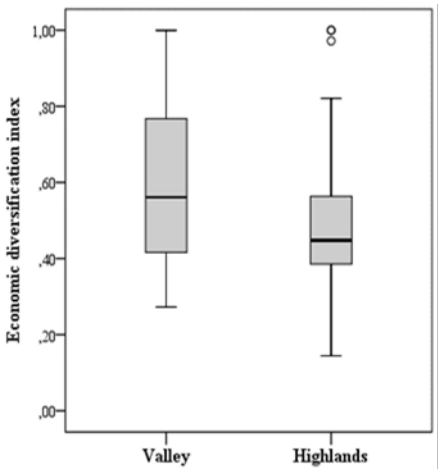


Figure 6.2: Economic diversity index calculated for the highlands (39 household interviews) and inter-Andean valley (44 household interviews), using Shannon-Wiever index.

6.2 Identification of poverty indicators

Hierarchical cluster analysis has identified three wealth groups: 1) better-off, 2) average and 3) poor (Table 6.4 and Table 6.5). The better-off group in both case studies was represented by households with better income (USD/day), bigger land, wider distribution of cultivated

plots inside the community and major access to different markets (local, regional and departmental). On the other side, poor households in both case studies presented a larger percentage of females as head of household.

Table 6.4: Household wealth categories based on the characteristic of the livelihood resources for the highlands based on 39 household interviews, during the agricultural year 2013.

Livelihood resource	***Better off Median (min – max) N = 11***	***Average Mean (min – max) N = 13***	***Poor Mean (min – max) N = 15***	***Kruskal Wallis Test***		
				Chi-square	***df***	***p***
Human capital						
Adults	2.00 (1 - 6)	2.00 (1 - 3)	2.00 (1 - 7)	1.730	2	0.421
Age of HH head	67 (33 - 77)	59 (26-76)	70 (43-88)	4.12	2	0.127
Education of HH head	4 (0-12)	5 (0-16)	3 (0-8)	7.615	2	**0.022** *
Female headed HH	15.4 %	30.8 %	53.8%	2.314	2	0.314
Health	0. (0 – 3)	0. (0 – 1)	1. (0 – 3)	6.743	2	**0.034** *
Language	3 (1-3)	3 (1-3)	3 (1-3)	5.842	2	0.054
% of migration	66.66 (0 – 85.71)	66 (0 - 80)	71 (0 - 90)	2.187	2	0.335
Natural capital						
Land	6.7 (4 – 14)	3.8 (0.6 – 9.20)	4. 8 (0.8 – 12.8)	7.456	2	**0.024** *
Crop distribution	3 (1 – 5)	2.0 (1 – 5)	1 (1-2)	10.24	2	**0.006** *
Cultivated surface	80 (70 -100)	80 (50-100)	60 (30-100)	5.153	2	0.076
Agrobiodiversity	15 (2 – 31)	12 (3 – 32)	8 (4-19)	2.981	2	0.225
Social and physical capital						
Social networks	2 (0 – 5)	3 (1 – 4)	1 (0 – 4)	2.592	2	0.274
Physical assets	4 (4 – 8)	7 (3 – 9)	5 (3 – 6)	16.105	2	**0.000***
Financial capital						
Total income	6.32 (2.21 – 28.51)	6.63 (1.01 – 21.05)	0.58 (0.01 – 10.38)	20.350	2	**0.000** *
Access to market	3 (0.58-3)	3 (0 – 3)	0.58 (0 – 3)	6.706	2	**0.035** *
technology	25.71 (0-42.86)	25.7 (11.4-71.4)	11.14 (0-42.86)	2.969	2	0.227
Irrigation	0 (0-0)	0 (0-50)	0 (0-100)	3.422	2	0.181

HH: household head; (*) represents significant differences between wealthy groups based on the non- parametric test of Kruskal–Wallis.

Table 6.5: Household wealth categories based on the characteristic of the livelihood resources for the inter-Andean valley based on 44 household interviews, during the agricultural year 2013

Livelihood resource	Better off Median (min – max) N = 15	Average Mean (min – max) N = 15	Poor Mean (min – max) N = 13	Kruskal-Wallis Test		
				Chi-square	*df*	p
Human capital						
Adults	2 (1 - 5)	2 (1 - 4)	2 (1 - 2)	0.385	2	0.825
Age of HH head	47 (28 – 67)	47 (30 – 73)	60 (50- 72)	9.57	2	**0.008** *
Education of HH head	6 (2 - 9)	5 (2 - 11)	3 (0 - 9)	6,438	2	**0.040** *
Female headed HH	33,3 %	46.7 %	61.5 %	2.175	2	0.337
Health	0 (0 – 3)	1 (0 – 2)	1 (0 – 2)	0.407	2	0.816
Language	3 (3 – 3)	3 (1 - 3)	3 (1 – 3)	3.702	2	0.157
% of migration	0 (0-66)	33(0-80)	50(0-87)	7.731	2	**0.021** *
Natural capital						
Land	6.4 (3.2 - 16.30)	5.28 (3 – 8.2)	4 (1.6 - 8)	10.563	2	**0.005** *
Crop distribution	5 (2 - 7)	3(1 - 5)	2 (1 - 6)	16.121	2	**0.000** *
Cultivate surface	90(40-100)	70(50-100)	100(50-100)	3.241	2	0.198
agrobiodiversity	4 (3 -12)	8 (2 - 13)	6 (1 - 11)	4.869	2	0.088
Social and physical capital						
Social networks	1 (0 - 5)	1 (0 - 5)	1 (0 - 3)	2.274	2	0.321
Physical assets	4 (3 - 10)	7 (4 - 8)	4 (2 - 9)	15.444	2	**0.000** *
Financial capital						
Total income	7.33 (2.57 – 21.33)	3.55(1.45-11.9)	2.11 (1.0–9.44)	12.798	2	**0.002** *
Access to market	7 (0 – 10)	10 (0 - 10)	0.75 (0- 10)	8.229	2	**0.016** *
technology	8.35 (0 – 37)	8.87 (0 - 34)	7.52 (0 – 31)	0.158	2	0.924
Irrigation	20 (0 -100)	25 (0 -100)	0 (0 -100)	0.794	2	0.672

HH: household head; (*) represents significant differences between wealthy groups based on the non- parametric test of Kruskal–Wallis

However, the results from household surveys point out different poverty indicators in the two case studies. For the highlands, health conditions of the household marked the difference between better-off and poor households, which means that the number of sick and disabled household members during the surveys was higher in the poor group. For the inter-Andean valley, the poor group is dominated by elderly people and the percentage of relatives that migrate permanently outside the community was significantly bigger in this group. In both

case studies, the average group presented intermediate values between the better-off and poor group. However, the household head had more years of education and the physical capital index was considerably higher than in the other groups.

Although both case studies are located in Municipalities under the category of poor (NPB 2011), the wealth ranking of the households allowed identifying the poorest households in the area. As cited by Kamanga et al. (2009) even in areas where most people are poor, one may still observe substantial wealth differences between groups of households. The poorest households are less able to deal with climate events because the lack the institutional, financial or technological capacity to adapt effectively (Fankhauser et al. 2014, Alary et al. 2011), and who lack effective coping strategies to deal with shocks and stresses (CARE 2011). Therefore, they present the highest vulnerability to the impacts of climate change at local level. Based on the findings, the poor group in both case studies are the most vulnerable. This group presented the lower income, less access to land and market, and fewer years of formal education. Additionally, this group presented a higher percentage of elderly and women as head of household. Overall, this group is the one left alone in charge of the farms and families, and has fewer alternative livelihoods when crops are lost. Similar characteristics of poor households were also described by Gentle and Maraseni (2012), Soltani (2012) McDowell and Hess (2012), and Ellis (1999).

As mentioned by van der Berg (2010) and Ticehurst (2009), the livelihood resources for the poorest are not sufficient to satisfy their basic needs. Consequently, they are the most exposed to climate change impacts and are more vulnerable during the response and recovery phase than their richer neighbors, especially when they cause not only losses of income but also losses in assets. The observed characteristics of the livelihood portfolio of poor households are pushing them towards more vulnerability and marginalization, not allowing them to leave the vicious cycle of poverty; defined by Jimenez (2013) and Gentle and Marasen (2012) as the lack of ability and assets to leave the condition of poverty.

In the highlands, the income analysis between three wealth groups shows that the off-farm and crop production were significantly bigger for the household under the category of better-off (off-farm: $z = 8.534$; $p = 0.014$; crop production: $z = 8.044$; $p = 0.018$), (Figure 6.3).

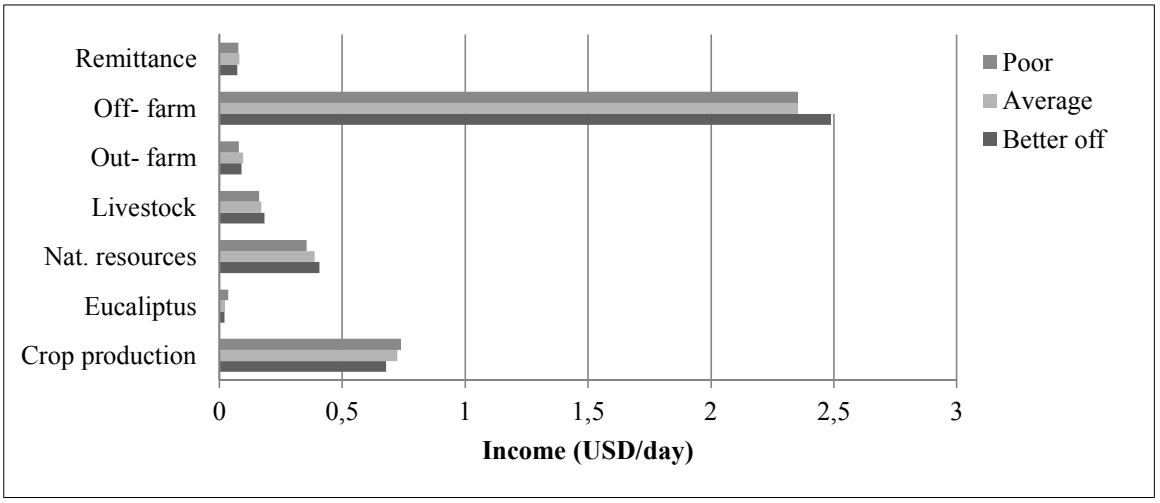


Figure 6.3: Income distribution according to the selected income categories for three wealth groups based on 39 household interviews for the highlands during 2013.

In the inter-Andean valley, similar patterns have been observed, and the income from off-farm activities was significantly larger for the households in the category of better-off ($z = 6.342$; $p = 0.039$; Figure 6.4). Moreover, in this case, out-farm activities based on the temporary migration of one or two household members to neighbor communities represent an important strategy because it allowed families to work together and share economic roles inside the household.

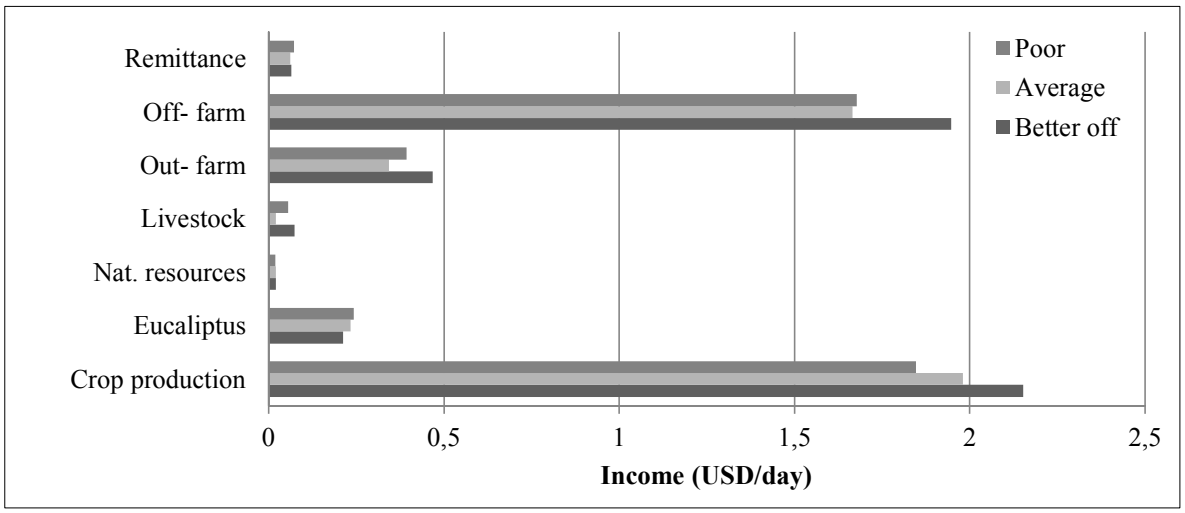


Figure 6.4: Income distribution according to the selected income categories for three wealth groups based on 44 household interviews for the inter-Andean valley during 2013.

The economic diversification index presents no significant differences between wealth groups in the two case studies (highlands: z = 1.097, *df* = 2, p = 0.578; inter-Andean valley: z = 0.056, *df* = 2, p = 0.973; Figure 6.5). It can be assumed that the diversity index is related to the geographic conditions and natural resources available in every region and not by the level of the wealth of the household.

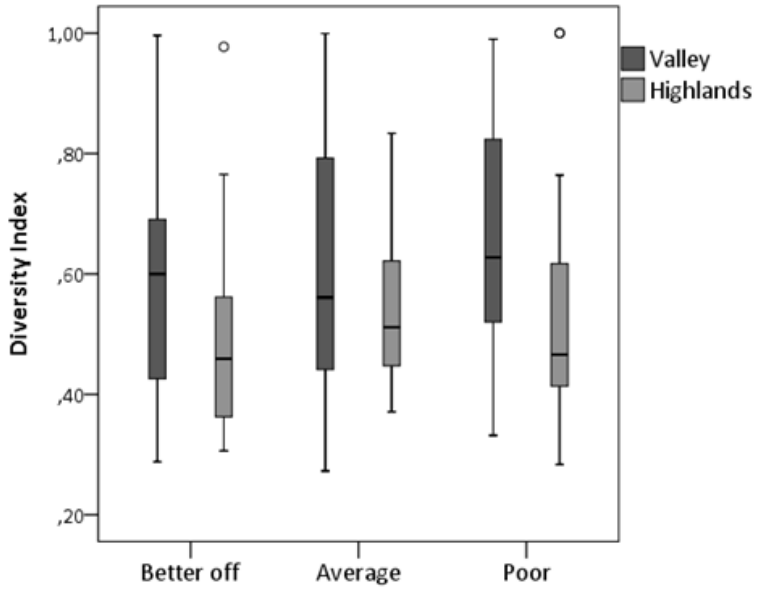


Figure 6.5: Economic diversity index between wealth groups in the highlands and inter-Andean valley, based on 39 interviews in the highlands and 44 interviews in the inter-Andean valley.

The redundancy analysis (RDA) combined a set of household characteristics including age, gender, health, migration rates, education, social networks, assets, livestock, access to the market, access to land, and income permits a step ahead on the understanding of parameters that guide the economic diversification. These contributed to the identification of poverty indicators in both case studies based on the household survey. For that, the RDA analysis has clustered the household resources and has related them to income distribution to show which household resources have contributed to the development of different economic activities and income sources (Figure 6.6).

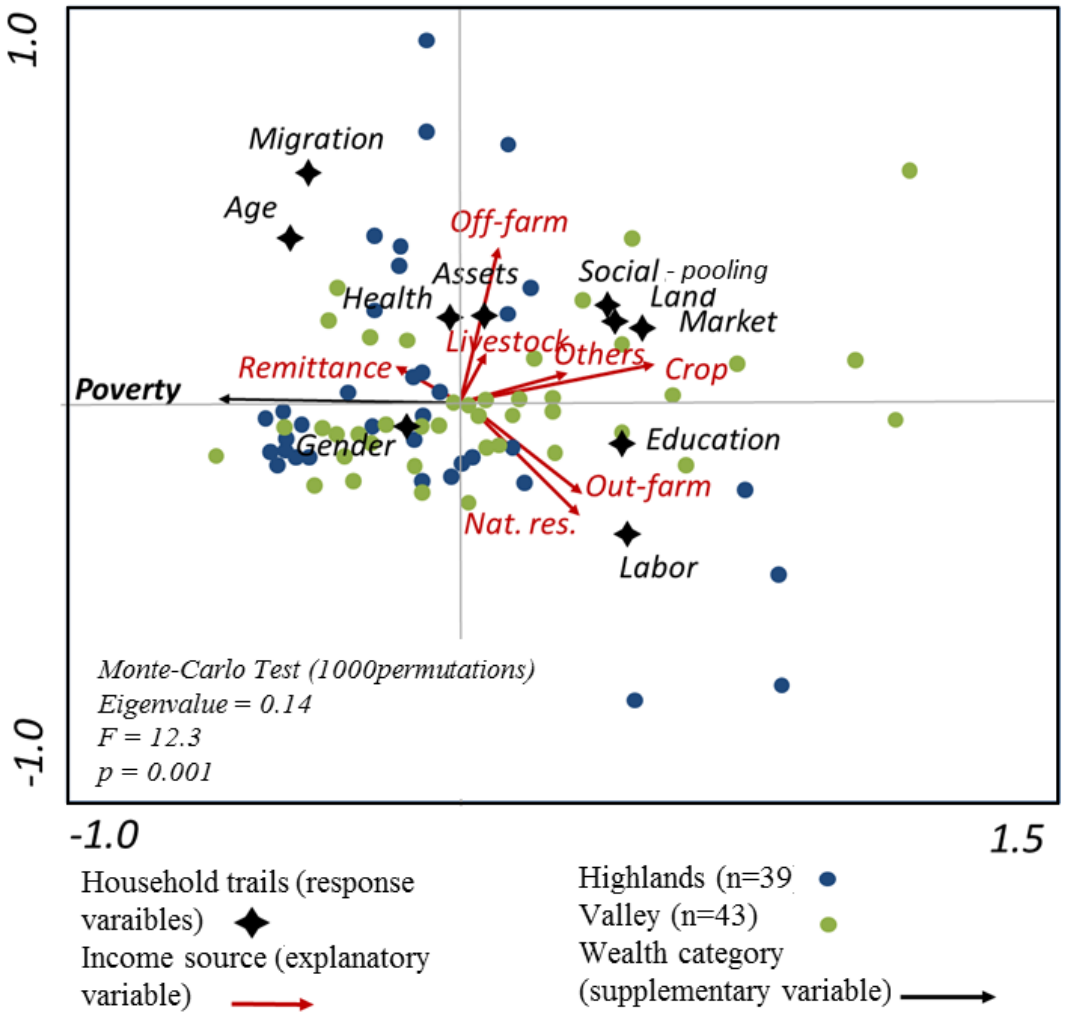


Figure 6.6: Key factors that drive poverty based on redundancy analysis (RDA) for highlands and inter-Andean valley.

The redundancy analysis (RDA) confirmed the results from the wealth ranking, and agreed on the fact that lack of livelihood resources in both case studies does not allow poor households to leave the condition of poverty. RDA shows poverty indicators related to traits like age (older people), migration and gender (major percentage of women as head of household), which seems to be a more prominent indicator for poverty and shows also a direct dependence on remittances (Table 6.6). In other words, old women living alone in the communities are not able to work on their own and depend on the support from relatives who send remittances for the provision of food and other goods. As has been seen, old women do not participate in community activities and remain most of the time isolated.

Table 6.6: Similar poverty indicators for highland and inter-Andean valley according to the redundancy analysis.

Poverty indicators	
Household traits	*Economic activity*
age gender (female) migration	Remittances and bonds

Research own derivation based on the results of the redundancy analysis

Social-pooling, as well as access to land and markets, were the main traits in wealthy households in the inter-Andean valley, whereas the main income sources were crop production and the income from Eucalyptus plantation (Table 6.7). For wealthy households in the highlands, the picture is diverse: 1) income from the natural resources-related activities (mainly fishing) and out-farm (mainly agro-tourism) were accordant sources if labor (household size) and education were available (Table 6.5), or at a smaller scale 2) income from off-farm and livestock were accordant sources when health and assets were available.

Table 6.7: Different wealth indicators for the highlands and valley according to the RDA analysis.

Wealth indicators			
Highland		*Inter-Andean valley*	
HH traits	*Income source*	*HH traits*	*Income source*
education land health/assets	natural resources-related activities (fishing) out-farm (eco-tourism) off-farm/ livestock	social-pooling labor health/assets	crop production Eucalyptus plantation

Derivated from the RDA based on 83 household interviews, where HH = household

The assessment of socio-economic strategies highlights the importance to integrate poverty reduction actions as adaptation strategies for climate change, giving special attention to vulnerable groups and gender. In the highlands, the results suggest that fishing (named as natural resource-related activity) has contributed significantly to the total income of the

household. Nevertheless, the availability of aquatic resources is unknown and depends on external factors which are not controlled by the fishermen. Therefore is not recommended to promote this activity as an accurate strategy for climate change adaptation. On the other hand, out-farm activities, e.g. Eco-tourism, have the potential to support the well-being of the household, but only to those households that showed better education and labor. By promoting eco-tourism as strategies, it can also prevent migration and could be used as a tool to attract young people back to the community. This economic activity becomes an attractive strategy for both sustainable resources use and poverty reduction (Soltani et al. 2012).

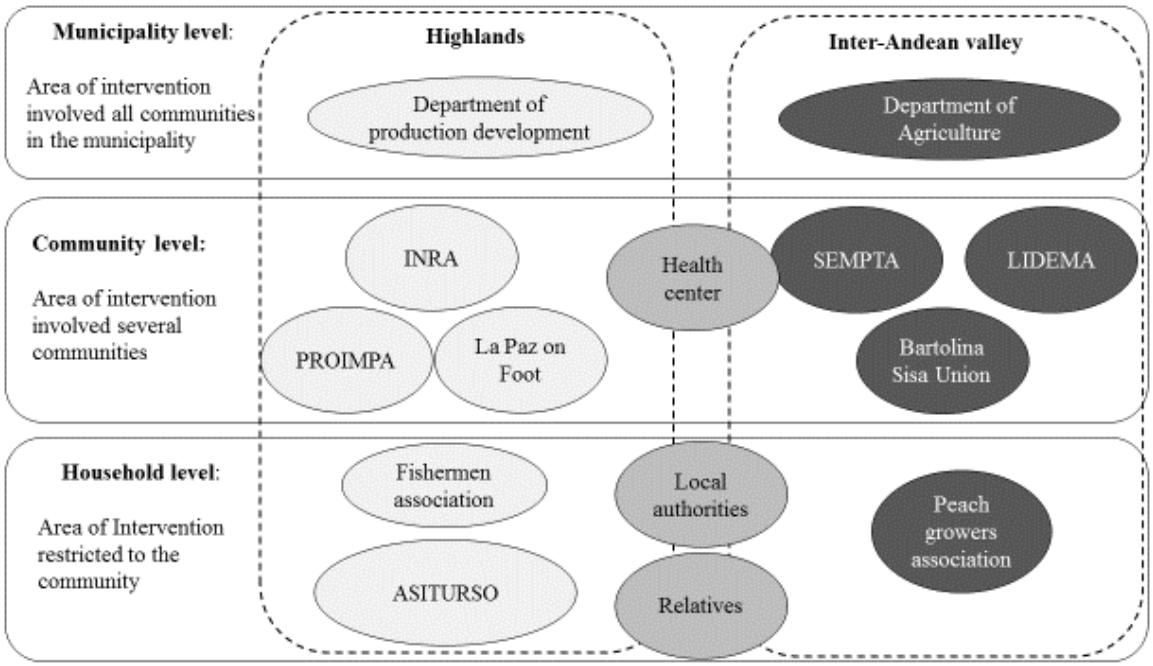
Promoting off-farm activities as strategies for poverty reduction requires further assessment, and taking into account that off-farm activities depend on work opportunities determined by skills, education, and gender (Ellis 2000). Moreover, as expressed above, reduced labor for the household represents a threat to the sustainability of the farm.

In the inter-Andean valley, out-farm activities have a significant contribution to income. The results show that farmers interchange farm labor inside the community and also in neighboring communities. These activities provide households with cash, labor, and other resources, e.g. food, but above all contribute to build a strong social network that contributes to secure food production and increase the well-being of the household. Another important activity is related to eucalyptus plantation. Most of the households that have eucalyptus see this resource as an investment that can be used in times of need, e.g. when the income from crop production is reduced or when they need to invest in technologies for the farm or education for the children. Moreover, the eucalyptus market is an important strategy to help farmers to deal with the risk of harvest loss in adverse climatic conditions. These strategies became more successful when there was the higher participation of the household in social networks and greater access to land and markets.

7. SOCIAL NETWORK STRATEGIES

7.1 Stakeholders involved in the social network

A total of 9 groups of civil organizations in the highlands and 8 in the inter-Andean valley have been identified as actors with a direct relationship to households in the selected case studies. Each one of these actors plays an important role in the daily life of local households. The interactions of these actors in the community are determined by the traditional social organization of local communities and current municipality regulations. Three categories of actors have been defined according to the area of intervention: municipality level, community level and household (Figure 7.1).



Research own derivation based on actors map assessment and key informant interviews.

Figure 7.1 Identification of actors that integrated the social networks in the highlands and inter-Andean valley.

Social organizations at the household level were mainly integrated by community members that live and work in the community. At the community level, the social organizations corresponded to local government and non-government organizations that work in the municipality with more than one community in coordination with the municipality and households. Finally, at the municipality level, the main actors were local authorities inside the municipality.

7.1.1 Municipality

The municipality is the institution responsible for ensuring the welfare of communities promoting rural development based on the physical, biological, social, economic, cultural and political characteristics of the area. The strategies used by the municipality are established in the Municipal Development Plan (PDM following its initials in Spanish). These strategies are focused on agricultural production, reducing poverty, health services, education and basic services, and conservation of natural resources (PDM-Inquisivi 2010; PDM-Puerto Carabuco 2008). To achieve the above objectives, each municipality is organized into departments, and each one of these departments has specific objectives to contribute to the main goal of the municipality.

The Department of Production Development in the municipality of Puerto Carabuco and the Department of Agriculture Production in the municipality of Inquisivi are the institutions responsible for ensuring the agricultural production and the use and management of natural resources. The staff of both institutions maintains a direct relationship with local authorities and farmers in rural communities. Above all, the main activity of both departments is to ensure that all demands from farmers are recorded for upcoming Annual Operating Plan (POA following its initials in Spanish). Once the demands are recorded, action lines are generated and a budget for each of these actions is designated depending on the number of beneficiaries. The decision is made with the participation of all local authorities from the communities during the main General Assembly.

The role of the Agricultural Department of Inquisivi in the communities of Sita and Chorocona (the case study of the inter-Andean valley) is directly related to the development and implementation of programs and projects focused on agricultural production and reforestation. On the way, these programs and projects also have the potential to contribute to food security, poverty reduction, education, health and overall on the well-being of the communities. The staff members of the department, local authorities and farmers in the community have weekly interactions under different scenarios: whenever the staff members visit the communities, during formal meetings, “Assemblies” or whenever the authorities or farmers travel to the capital of the municipality and visit the office of Agricultural Department. During the interaction among these actors, farmers are able to express their concerns on problems related to agriculture production or related topics. The technical staff of

the department assists the public demands of farmers; most of the actions are related to pest control and management and improving the water irrigation system, food production, seeds, maintenance of communal roads and the main road, and water storage tanks.

The Department of Production Development in the municipality of Puerto Carabuco, Santiago de Okola (case study – highlands) supports agriculture, livestock, and fishing activities in the region. The relationship between staff members of the department and the community is limited to the monthly meetings in which all important topics related to the agricultural production and related activities are discussed.

7.1.2 INRA – Instituto Nacional de Reforma Agraria

National Institute of Agrarian Reform is one way the national government is in charge of delimiting and providing titles of land ownership. An INRA delegate is responsible for visiting the community and elaborating a complete assessment of the land and defining the limits of the property. This work is done in conjunction with local authorities and the families that are occupying the land. Whenever there is a conflict between neighbors, both parts must be present during the assessment of the land to avoid conflicts and existing documents must be presented. At the moment, land titling is an ongoing process in the highlands, but not yet in the valley. Until now, the distribution and use of the land follow the structure of a "*sayana*". Therefore, two type of ownership are identified: private land and community land. Private ownership of land is given through inheritance and the community land is for the use of all members of the community under local regulations.

7.1.3 Local authorities

The local authorities or "native authorities" act in the face of the community in front of the municipality and other social organization. They follow local regulations based on the use and traditional customs of the communities. The responsibilities of native authorities are the internal coordination of local actions, the representation of the community in the face of public and private organizations, the coordination and management of actions related to agricultural, social, cultural, athletic and spiritual development, including the performance of traditional ritual related to the Aymara culture. 13 representatives of the community are selected among the community members to integrate the teamwork of the native authorities.

Every household has the obligation to take over a leader position at least one time, providing the community with skills, knowledge, and experience (Ziche y Rist 2001).

The native authorities maintain a close relationship with community members whenever they are requested, especially when there is a need to resolve a conflict. The organizational work of native authorities is discussed during monthly community meetings in which different topics related to the well-being of the community are discussed, for example, agricultural production, land titles, basic services distribution, community work, access to water, and conflict resolution. Moreover, native authorities are responsible for expressing community needs during the monthly meetings at the municipality. During the assessment of social networks, four native authorities were highlighted from among the other authorities due to their involvement with the local households; therefore, their activities were recorded and included in the assessment. These authorities were:

- ***Leader and sub-leader*:** both authorities have the responsibility of the organic and harmonic function of the community. They are the main point of connection between community members, social organizations and municipality authorities.

- ***Committee of irrigation*:** native authority responsible for the implementation and maintenance of the irrigation system in the community. This person has a direct contact with all native authorities. Moreover, is the person in charge of coordinating the community work for: building water channels, cleaning roads, and water distribution for agriculture.

- ***Committee of water*:** native authority responsible for the access and distribution of water among community members. This person has a direct contact with all members of the native authorities and works in close relationship with the committee of irrigation.

7.1.4 SEMPTA – "*Servicios Múltiples de Tecnologías Apropiadas*"- (Multiple services of appropriate technologies)

SEMPTA is a non-governmental non-profit organization responsible for implementing the National Program of Bioculture (NPB) in the municipality of Inquisivi since 2010. The main

objective of this program is to contribute to the living well of the local communities, food security and conservation of the Andean ecosystems through sustainable use of its biodiversity, respect, and cultural appreciation. The program has direct action on: agricultural production (reinforcing soil management, promoting food diversification, improving current agriculture practices, looking for new, more resilient crops and diversifying the diet), conservation (promoting the use of native tree species for reforestation, conserving traditional knowledge on forest management), and elaboration of local regulation on the use and management of resources based on traditional knowledge. Project coverage reaches 35% of the households in the municipality.

SEMPTA has a direct relationship with the municipality, social organizations, and households. This relationship is based on agreements and local regulations. At the municipality and community levels, the agreement establishes the responsibilities of staff members, distribution of budget, use and maintenance of technologies and materials, and the working plan. The relationship with local households is based on a working plan that includes: workshops, control and monitoring agricultural production, and implementation of irrigation systems. At the same time, SEMPTA works in close relationship with LIDEMA on the implementation of the "Livelihood vulnerability reduction to climate change program".

7.1.5 LIDEMA – *"Liga de Defensa del Medio Ambiente"* (League of Environmental Protection)

This organization works at the national level. Its aim is to contribute to the sustainability of livelihoods by promoting the adoption of models for environmental development, economic and social sustainability, incorporating knowledge dialogue, reversing the deterioration of the productive bases, and reducing vulnerability to the effects of climate change, both in urban and rural areas, within the framework of equity and poverty reduction. Currently, LIDEMA is implementing the "Livelihood vulnerability reduction to climate change program" at the national level, in which the municipality of Inquisivi is considered one of the intervention areas. Here, the implementation of the program is done by SEMPTA.

7.1.6 Bartolina Sisa Union

The Bartolina Sisa Union is a social organization formed by women with the objective of driving the growth of manufacturing activities related to the female population. The range of

action is nationwide, but at the moment, it is not active in the highlands. In the valley, women are engaged in the production of blankets, leather ties, and fiber ropes. All women have the opportunity to participate in the activities planned by the Union, but their participation is limited by time availability; whenever the agricultural and domestic activities are covered, then the women can participate. The activities developed by the Union are not restricted to women, and the number of men participating has been increasing in the last years. Young generations also take part in the activities in the school. The benefit of participating in the projects of the Union is to gain experience and training in diversifying the manufacturing and providing the household a new source of income. The leader of the Bartolina Sisa Union in the community has a direct relationship with other women inside the community and also with other Bartolina Sisa leaders from other communities at the municipality level.

7.1.7 La Paz on Foot (LPOF)

La Paz on Foot is a locally owned and operated travel program and services brand established in 2004 and operated by Sendas Altas, SRL. For the past decade, LPOF has been designing, organizing and operating innovative responsible tourism programs in La Paz and throughout the Central Andean region. The main objective of this institution is to promote responsible travel as a tool for sustainable development and biodiversity conservation. LPOF manages several small, community-level projects aimed at improving the quality of life in the communities where tourism activities are carried out. Funds come from several international donor agencies and execute development and conservation projects and consultants work on projects focused on community-based tourism and biodiversity conservation.

Since 2005, the community of Santiago de Okola (case study – highlands) works together with LPOF to provide responsible tourism activities. LPOF assisted local families in the formation of their own community-based agro-tourism association: Integral Tourism Association of Santiago de Okola (ASITURSO), by helping with the legal certification and bringing training for tourism based on how to improve services. This training consisted of a series of workshops on food, guides, administration, and accommodation, and is based on local traditions and customs. Moreover, LPOF helped on the elaboration of a web page: www.santiagodeokola.com, to promote tourism activities in the community. LPOF keeps a formal relationship with 24 member families of ASITURSO, and close communication with local and municipality authorities in order to work inside the community.

Further, it works closely with the local organization PROIMPA in a project related to conservation of agrobiodiversity and supports research programs for university bachelor degrees.

7.1.8 ASITURSO: "*Asociación Integral de Turismo de Santiago de Okola*" Integral Tourism Association of Santiago de Okola

ASITURSO, a community-led and managed association has started in 2008 in collaboration with several national and international organizations. The aim of this association is dedicated to the development of sustainable resource use and management, principally through an agro-tourism project that seeks to help conserve traditional crops, crop varieties, and associated cultural practices, reverse the flow of youth from the village to urban areas and to increase incomes of community members and their families. The association is integrated by 24 local families which are in the process of developing their own by-laws and statutes, identifying positions and responsibilities within the company, and receiving training in hygiene, hosting services and other important skills to provide good services to national and international tourists.

The focus of the agro-tourism activities developed by the association is to show the rich agricultural heritage of the community in particular and the Lake Titicaca region in general. The Lake Titicaca region is widely considered the center of origin of several crops of worldwide importance, such as potato and quinoa. Apart from the conservation of this important agricultural diversity, the community members preserve many others traditional crops and cropping practices that represent the potential to promote agro-tourism activities by the association. Agro-tourism is tourism focused on agricultural in all senses; therefore, the association offers local dishes, learning about food and crops, and understanding more about the threats to the farming system, such as rural-urban migration and globalization. Currently the association offers for national and international tourist programs related to: homestays (including overnight with breakfast, lunch and dinner), traditional "*apthapi"* lunch (a variety of local foods are served at a communal table), local guide for community walks, workshops on traditional weaving, agro-biodiversity, Andean cooking and medicinal plants.

7.1.9 Fishermen association

Currently, fishing activities are threatening by indiscriminate catch of fish and the high level of contamination of the Lake Titicaca, pollution with waste bags and plastic bottles, causing an excessive rise in prices in the market. Moreover, fishermen use nets of "nylon monofilament" which is more effective but at the same time is a threat for small fishes under a reproductive cycle. Therefore, the existence of fishermen association contributes on the sustainable use of the aquatic resource

In the community, 23 families are active members of the fishermen association. Fishing activities are regulated by law and controlled by the association. Every member of the association has a designated area for fishing and established the quota of fish according to the season, abundance of fish in the lake and market conditions. Fishermen in the community collaborate mutually based on the existing local agreements but also based on the traditional customs that guide the relationship among families and neighbors in the community (See also section 6.1.1).

7.1.10 Peach producers association

A total of 24 families integrated the association. The objective of this association is to share knowledge and experience on peach plantations. This association takes care of every step in the production starting with the pest management, soil conservation techniques, harvesting, transformation, transportation and commercialization of the product. This association has been established with external cooperation but currently is managed in an organized way among the members. The peach association has internal regulations that guide the participation of each member following a structured organization. The leader and sub-leader are in charge of the fulfillment of tasks related to the production of peaches, seek for new markets, purchasing machinery (for the dehydration of the fruits), construction of new infrastructure and other activities. At the same time, these authorities have the responsibility to attend all important meetings at the community and municipality level. The relationship between the association and other stakeholders depends on the regulations established in the community. Among members of the association, the interaction is permanent; the frequency of meetings depends on the planned activities and the cycle of the peach production.

7.1.11 Households

The relationship among households is based on the implementation of *ayni* and *minka*. All registered members in the community are required to attend community meetings, participate in community work, and meet the quotas to the community according to the number of members in the household. Whenever the head of the household cannot meet its obligations, then the household head can be substituted by another member of the household.

7.1.12 Relatives

Relatives living outside the community have an important role in the well-being of the local families and therefore were considered as part of the social networks mainly for two reasons. On one hand, local families received economic support from the migrants and, on the other hand, the migrants came back to the communities during the planting and harvesting time to support the local families (see sections 4.1.1 and 4.2.1).

7.2 Existing social networks in the highlands

7.2.1 Formation of social networks in the scenario of socio-economic conflicts

In previous chapters (see section 4.1), the socio-economic problems and the coping strategies assumed by the households were described (see section 5.1). Here, the explorative analysis of social networks described the relationship among actors (households, social organizations and authorities from the community and the municipality), when households were facing socio-economic stress in their daily lives. The identified social network (Figure 7.2) shows the way in which 58 actors are related to each other and displayed a total of 325 interactions. The visualization of this social network established the position of every actor in the network identifying: 1) sub-groups: small groups of actors that share a common activity; 2) bridging actors: actors located between two or more sub-groups; 3) periphery actors: actors integrated into the network for fewer than two interactions.

Three sub-groups have been identified: sub-group *A*, integrated by both local and municipal authorities, the formation of this sub-group indicates that local authorities work together to support households when they are facing socio-economic problems. The interactions of this sub-group occurred during general assemblies, communal meetings, and extra-ordinary

meetings. During these events, the actors analyzed and developed strategies to cope with a variety of socio-economic conflicts. The sub-group *B* integrated household members of the Integral Tourism Association of Santiago de Okola (ASITURSO) and La Paz on Foot (LPOF). The distance between the actors in the network is similar, meaning that the actors cooperated with each other and their participation in the association is equitable. The sub-group *C* integrated households whose main interaction among them was fishing. The distance between the actors varied, showing preferences of interaction inside the group. The periphery actors, located on the edge of the network were households poorly integrated into the network by one or two interactions. In contrast, bridging actors were located in the center of the network linking sub-groups; these actors have different roles inside the community, as will be described below.

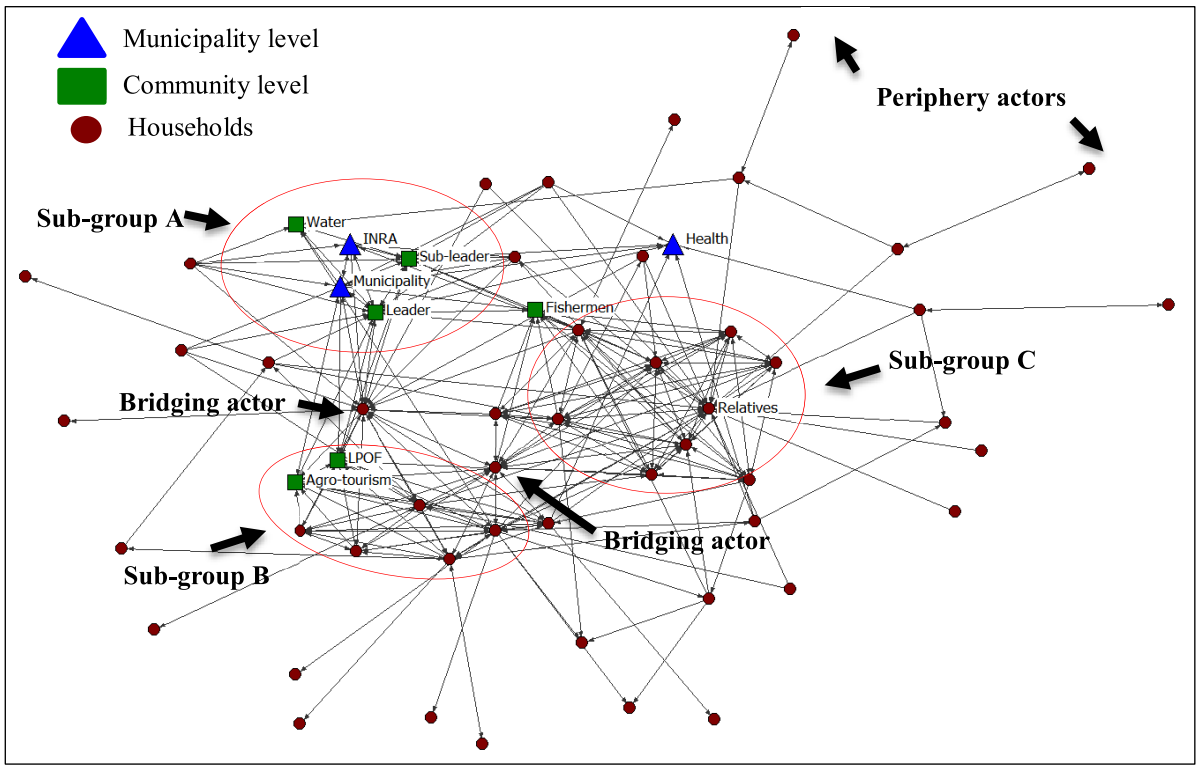


Figure 7.2: Structure of social network in the highlands based on the interaction of 58 actors whenever a socio-economic conflict was threating the well-being of the households.

The relationship between a pair of actors in the network to face a given socio-economic problem was diverse. During the survey, when asking the households: "Who helps you?" and "What do you do together?", the common answers were: "*I ask for help from the authorities for…, I work together with my neighbors on…, I have help from relatives on…*". To better

understand the relationship between actors, and the strategies assumed, the answers were classified into six categories.

Table 7.1: Description of the strategies to cope socio-economic conflicts, based on the interaction of 58 actors from the highlands.

Strategy	Description
Fishery	The relationship between fishermen included: compliance with internal rules and agreements in the association. The relationship between the head of the association and local authorities is related to administrative and organization activities.
Agro-tourism related activities	The relationship within the members of the Integral Tourism Association of Santiago de Okola (ASITURSO) established the participation of training programs, teamwork on signaling and maintaining tourist paths, planning activities, and compliance with the internal regulation. The relationship ASITURSO – LPOF established training programs on services, food and hygiene, and infrastructure. And the relationship LPOF – local authorities established the agreements and permissions to operate in the community.
Agricultural production	This relationship occurred mainly among community members based on the reciprocal work in agricultural production: *minka* and *ayni*. The activities developed included: planting, harvesting, and performance of rituals.
Organization and planning	This relationship occurred mainly among authorities from the communities and municipality and the head of social organizations, included activities related to the development and implementation of programs and projects, budget distribution, and administration activities, with emphasis on reinforcement of infrastructure, provision and regulation of basic services, access to land and other resources, conflict resolution, and establishment of agreements among stakeholders. This relationship also occurred between households and authorities and it contributed to the flow

	of information.

Continuation…

Familiar relationship	This relationship occurred between permanent residents of the community and a relative living outside the community. The interactions between this pair of actors supported local families to cope with socio-economic conflicts. Relatives living outside the community contributed with remittances and/or temporary labor during the harvesting season.
Healthcare	This relationship is related to the need of a household for health care from the local health center.

Own research derivation based on household and key informant interviews (see Figure 7.3).

This classification has been made based on the principal motivation for the interaction assumed by the pair of actors. Therefore, the 325 ties – number of interactions – have been grouped in: 1) 94 pairs of actors sharing fishing-related activities, 2) 79 pair of actors sharing agro-tourism-related activities, 3) 62 pair of actors sharing agriculture production activities, 4) 53 pair of actors sharing organization and planning-related activities, 5) the interaction between 32 pairs of actors relying on familiar relationship, and 6) the interaction of four pairs of actors relying on health care-related activities (Table 7.1; Figure 7.3).

The integration of a household in a sub-group brought new knowledge and opportunity to secure the well-being of the family. For instance, households that participated in ASITURSO added a set of new resources and knowledge related to agro-tourism activities that represent a new strategy to secure the income of the household, providing the families an extra economic activity with the potential to improve the well-being of the household. For households that have participated in fishing activities, the existence of regulations and agreements between fishermen support the development of this activity, avoiding internal conflicts in the sub-group.

Moreover, the explorative analysis of the social network also contributes to identifying actors that have the potential to access and share goods and knowledge from other actors in the network. The identification of these actors was based on degree centrality measurement that calculated the number of interactions of each actor in the network. This measurement highlights the actors with more interactions (Figure 7.3). Once the actors were identified, the role of each of them in the network is described. A total of four households have presented high degree centrality: households *F40, F47, F24,* and *F16*. The position of these households in the network facilitated the implementation of strategies to cope with the socio-economic problem. The household *F40* allowed the flow of information between the fishermen and local authorities, having the responsibility to inform the authorities about the local situation and vice versa, to inform the fishermen about strategies planned in the municipality. The households *F47* and *F24* were the bridge between the sub-groups *B* and *C*, and their position pushed them into a convenient situation in which they received benefits from both sub-groups; at the same time, they contributed to the communication between these two sub-groups.

The household *F16* played an important role in the linkage between several sub-groups including the authorities: its enrollment with different community members allowed him to be integrated into several sub-groups and participate in different activities in parallel: political activity with the authority meetings, member ASITURSO, and the fishermen association. The head of this household also developed different functions inside the community, for instance: veterinary and local healer, therefore representing a key actor in the network. As shown by Rodima-Taylor (2012) for the case of Kuria, the role of one actor in various local work groups and associations served to provide access to more resources and entitlements. Therefore, the individuals who belonged to various groups were frequently more successful in their diversified activities than those whose integration in the network was made by one tie.

Relatives living outside the community presented the highest degree centrality, suggesting that a significant number of households rely on their support to cope with socio-economic problems. The support that local families received from relatives living outside the community was remittances in times of scarcity and labor for crop production. In contrast, actors located on the periphery of the network presented the lowest degree centrality, keeping a relationship with one or at most two actors in the network, for the interchange of labor on

agricultural production. On the search for variables that explain the differences between actors with different degree centrality, the correlation analysis showed that actors with a low degree centrality are also the actors with the lowest rate of income (Pearson Correlation = 0.597; p = 0.000; Figure 7.3), indicating that households that have more interaction with other actors have more social capital (Ensor and Berger 2009).

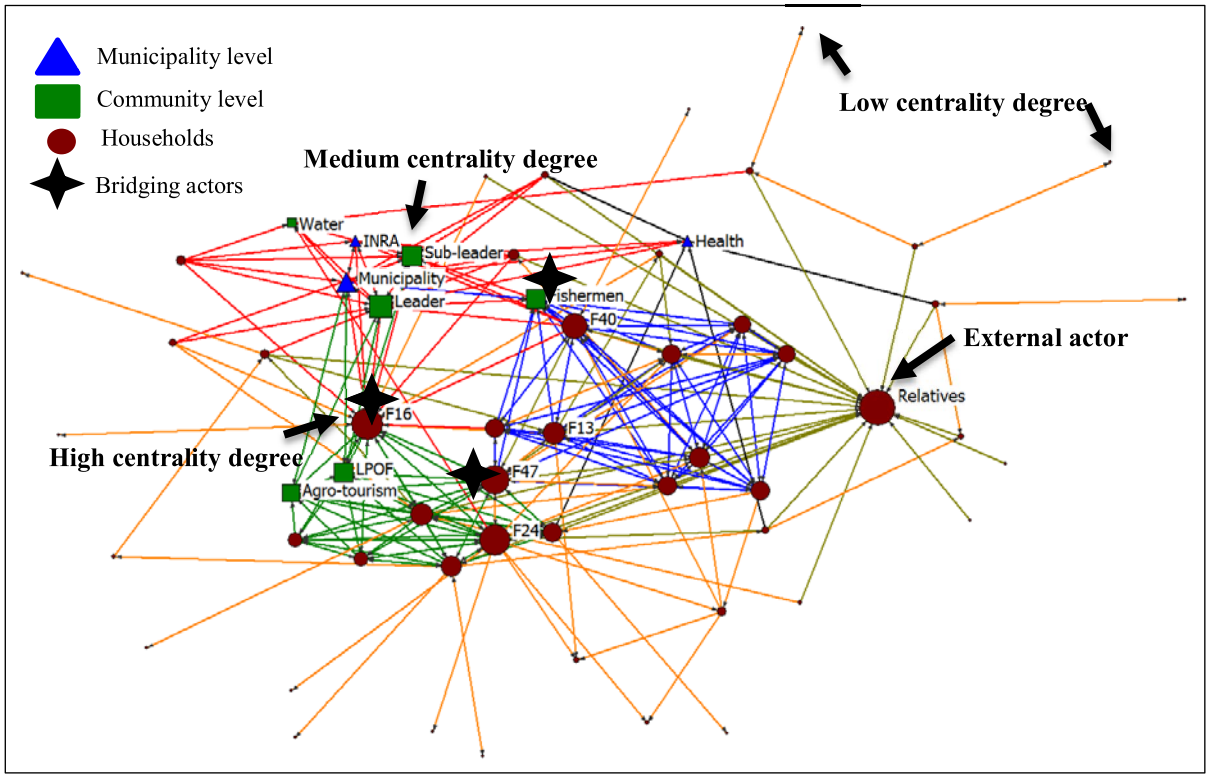


Figure 7.3: Categorization of strategies implemented between a pair of actors to cope with a socio-economic conflict and centrality degree in the highlands. Where the strategies are represented with lines (ties) in different colors: green = relationship related to agro-tourism activities, red = relationship related to organization and planning activities, yellow = agricultural production-related activities, blue = activities related to fishing, and light brown = relationship between local households and relatives living outside the community. The degree centrality is represented in the sociogram using different sizes of the actors' symbol; a bigger size represents high degree centrality.

7.2.2 Formation of social networks in the scenario of extreme weather events

The impact of extreme weather events and the coping strategies have been presented in previous chapters (see sections 4.1.5). Here, the explorative analysis of social networks described the relationship among actors whenever an extreme weather event threatens the well-

being of the families. The identified social network shows the way in which 52 actors are related to each other, and displayed a total of 153 number of interactions among them (Figure 7.4). In this network, most of the actors presented three or fewer interactions. The common answer given by the households was: … *"There is nothing we can do, we have to work alone in the field and try to recover our production, sometimes we do minka or ayni with neighbors or relatives. We ask for help from the authorities but their support comes later".*

The visualization of the social network established the position of every actor in the network identifying: 1) two sub-groups, 2) three bridging actors, 3) external actors, and 4) several periphery actors (Figure 7.4). The sub-group *A*, integrated by three actors from local and municipality authorities, showed that these actors work together to face the impacts of extreme weather events. Sub-group *B* integrated only by household. The bridging actors identified were: the sub-leader, whose role was to receive reports of damages or problems related to extreme weather events from households and transmit them to higher authorities; and two bridging actors, who were located among the two sub-groups facilitating the interaction between a large number of households with the authorities. The external actors, relatives living outside the community, also took part in the network with single relationships with family members living in the community. Finally, a total of 23 peripheral actors (households) were integrated into the network through a single relationship and eight actors by two relationships.

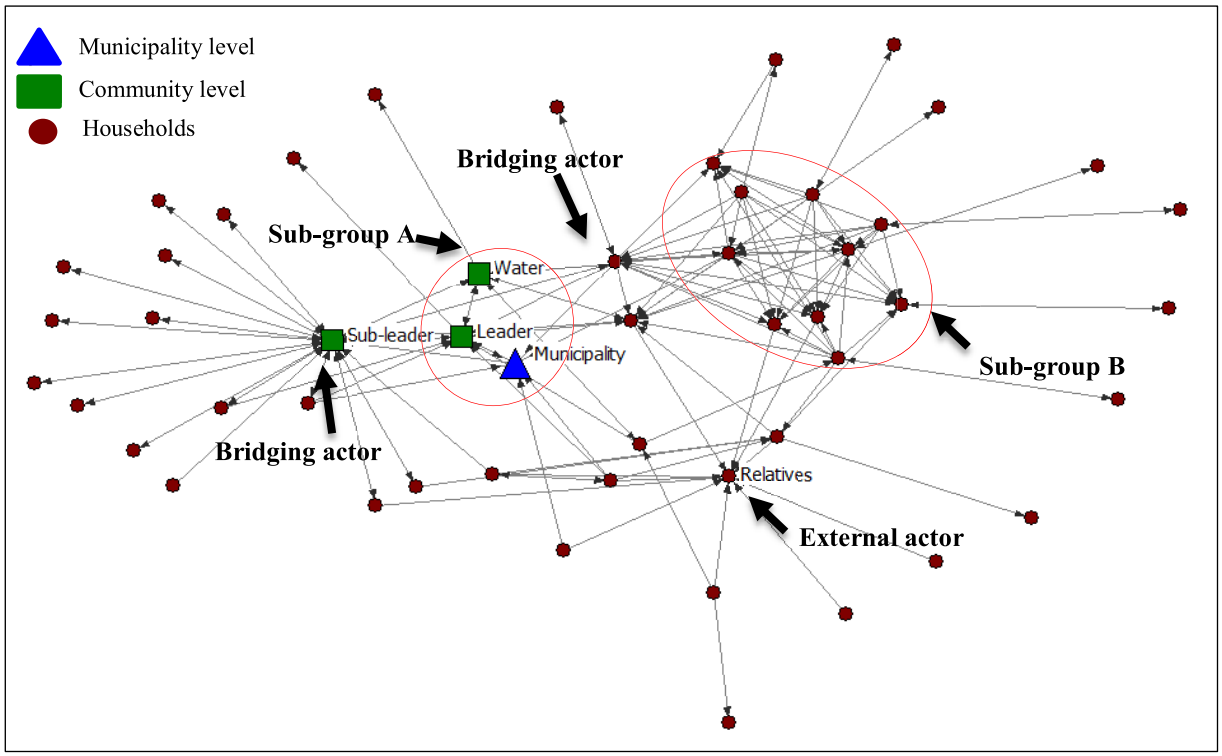


Figure 7.4: Structure of social network in the highlands based on the interaction of 52 actors whenever extreme weather events were threatening the well-being of the household.

The relationship between the actors allowed the implementation of three main sets of strategies related to: 1) 74 pairs of actors shared agricultural production activities; most of these activities focused their attention on the improvement of water channels and on labor during sowing and harvesting days. The share of labor in agriculture followed the traditional organization of the *ayni* and *minka* in which actors work together in a reciprocal way to improve agricultural production and avoid crop damage related to climatic threats. 2) The interaction of 61 pairs of actors was focused on organization and planning-related activities; when the interaction occurred among authorities, the focus was given on the implementation of mitigation strategies and the elaboration of a risk management plan; when the relationship occurred between a household and an authority, the household asked for support from the authorities and informed about the situation, then if possible the authority looked for a solution immediately or informed other authorities in higher positions about the situation and provided support to the affected families. As reported by households, sometimes the authorities contributed new seeds and facilitate technologies; however sometimes the budget was not enough to cover all the needs of the households. 3) The interaction between 18 pairs of actors is based on familiar relationships between households and relatives living outside the community. This interaction provided economic and labor support to local families after the impact of climatic events (Figure 7.5).

The centrality measures highlight the importance of the role of both: the sub-leader and the relatives living outside the community. Both actors presented a high degree centrality and played a central role in the implementation of strategies to cope with extreme weather events (as described above). They have been related mainly to actors that showed the lowest degree centrality, meaning that this relationship was the only strategy assumed. Households with a medium degree centrality gathered in sub-group *B* (Figure 7.4) based their relationship on sharing labor for agricultural production in a similar way; therefore, they have similar opportunities to secure food production (Figure 7.5). Here, the households *F14* and *F03* contributed to the connection between the sub-group and local authorities.

The relationship between the municipality and households showed a low degree centrality. That means households do not rely on the municipality when extreme weather occurs. Local testimonies during household survey pointed out the importance to focus attention on the crops as soon as an extreme weather event hits the area in order to secure food production. Therefore, the most important resource in this particular moment is labor; those households that have more interactions with other households have more chances to share labor to protect their crop production.

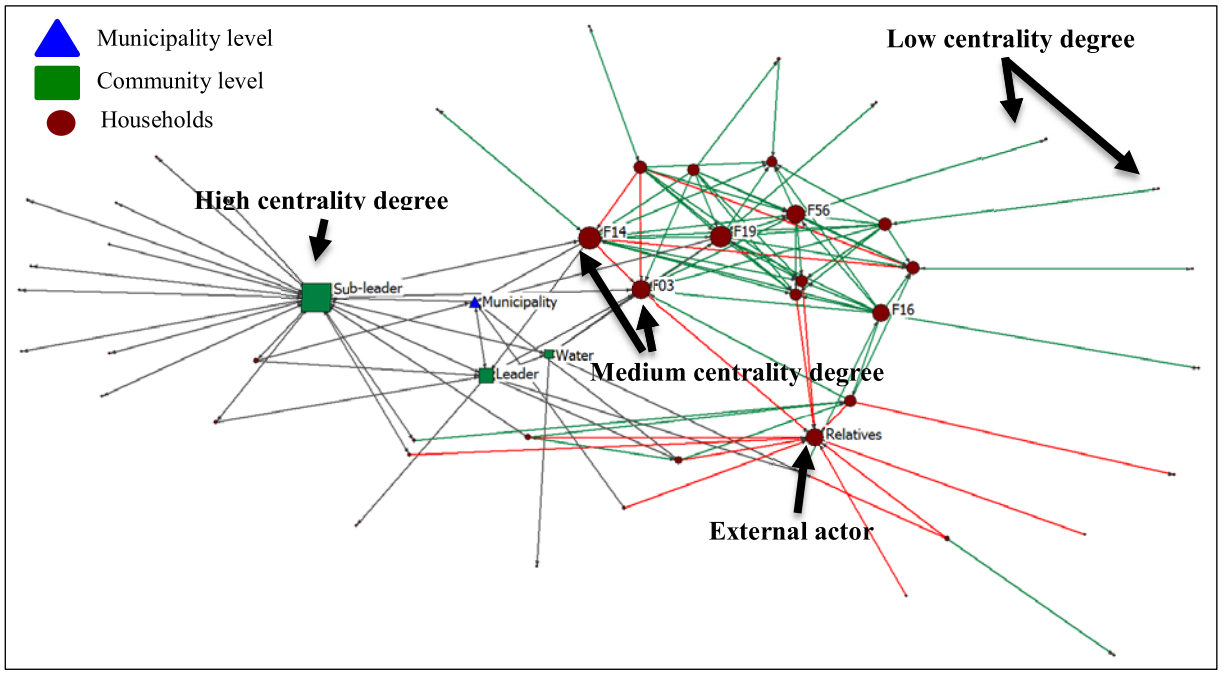


Figure 7.5: Categorization of strategies implemented between 52 pairs of actor to cope with extreme weather events and degree centrality in the highlands. Where the strategies are represented with lines (ties) in different colors: green = agriculture production, red = support from relatives living outside the community and silver = organization and planning of activities; the degree centrality is represented in the sociogram using different sizes of the actors' symbol; bigger size represents high degree centrality.

7.3 Existing social networks in the inter-Andean Valley

7.3.1 Formation of social networks under socio-economic conflict context

In previous chapters (see section 4.2.4), the socio-economic problems and the coping strategies assumed by the households have been described. Here, the explorative analysis of

social networks described the relationship among actors (households, social organizations and authorities from the community and the municipality), when households were facing a socio-economic stress in their daily life. The identified social network (Figure 7.6) shows the way in which 72 actors are related to each other, and displayed a total of 616 number of interactions. The visualization of the social network established the position of every actor in the network identifying: 1) two sub-groups, 2) bridging actors, and 3) several periphery actors.

Sub-group *A* showed the interactions mainly among community and municipality authorities. Sub-group *B* showed the interactions only among households. Nevertheless, the separation of these sub-groups is not well defined, and the sociogram showed several bridging actors between these two sub-groups. Two bridging actors, SEMPTA and the Agricultural Department from the municipality, were the principal link between households and authorities. These actors played a central role in the implementation of National Program of Bioculture (NPB), and they had the support of other bridging actors in the integration among households participating in the PNB. The sociogram also showed several actors located on the periphery of the network. These actors are integrated into the network by fewer than three interactions with other actors (Figure 7.6).

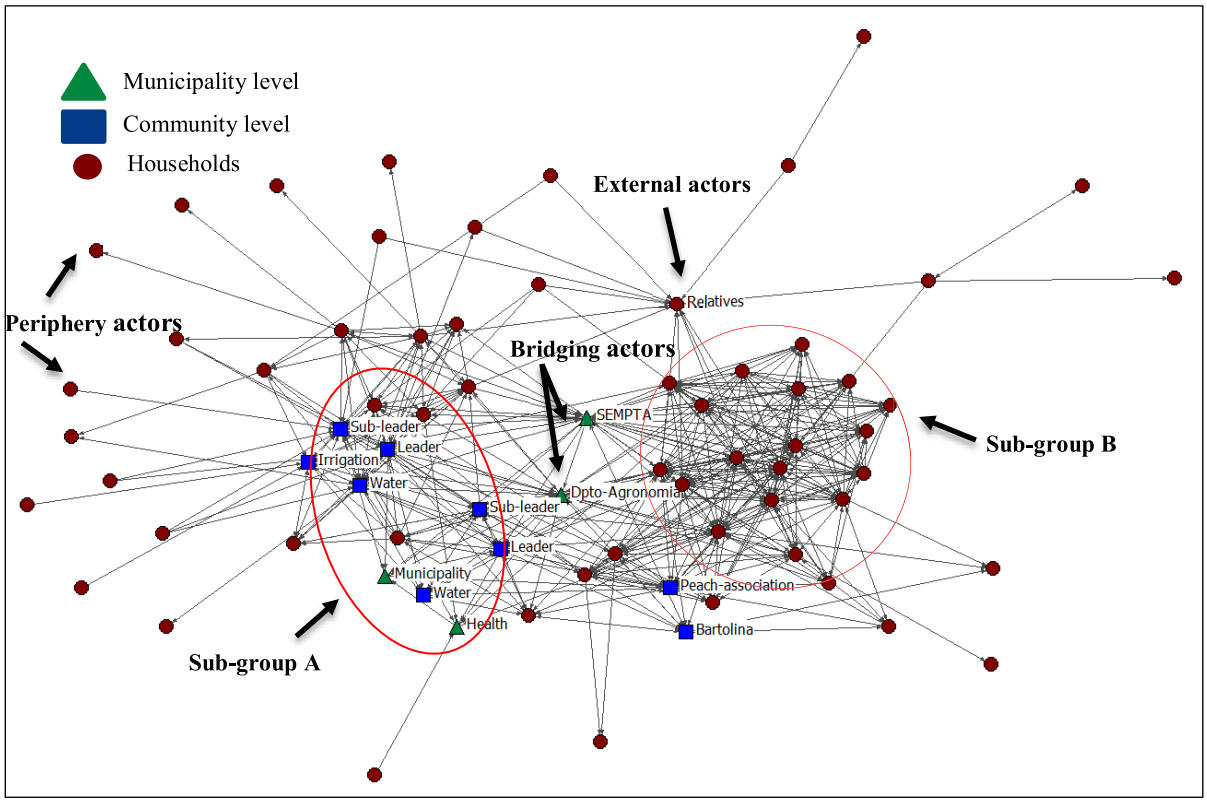


Figure 7.6: Structure of social network in the inter-Andean valley based on the interaction of 72 actors whenever a socio-economic conflict was threatening the well-being of the households.

The assessment of degree centrality classified the actors according to the number of interactions in three categories: 1) Actors with high degree centrality (higher number of interactions) were SEMPTA and the Agricultural Department. Their strategic position in the network contributed strongly to the implementation, development and monitoring of the ongoing PNB and other activities in the communities. 2) Actors with medium centrality were the community leaders well connected among themselves and with households. 3) Actors with low centrality were mostly households that did not participate in the PNB or other activities in the community (Figure 7.7).

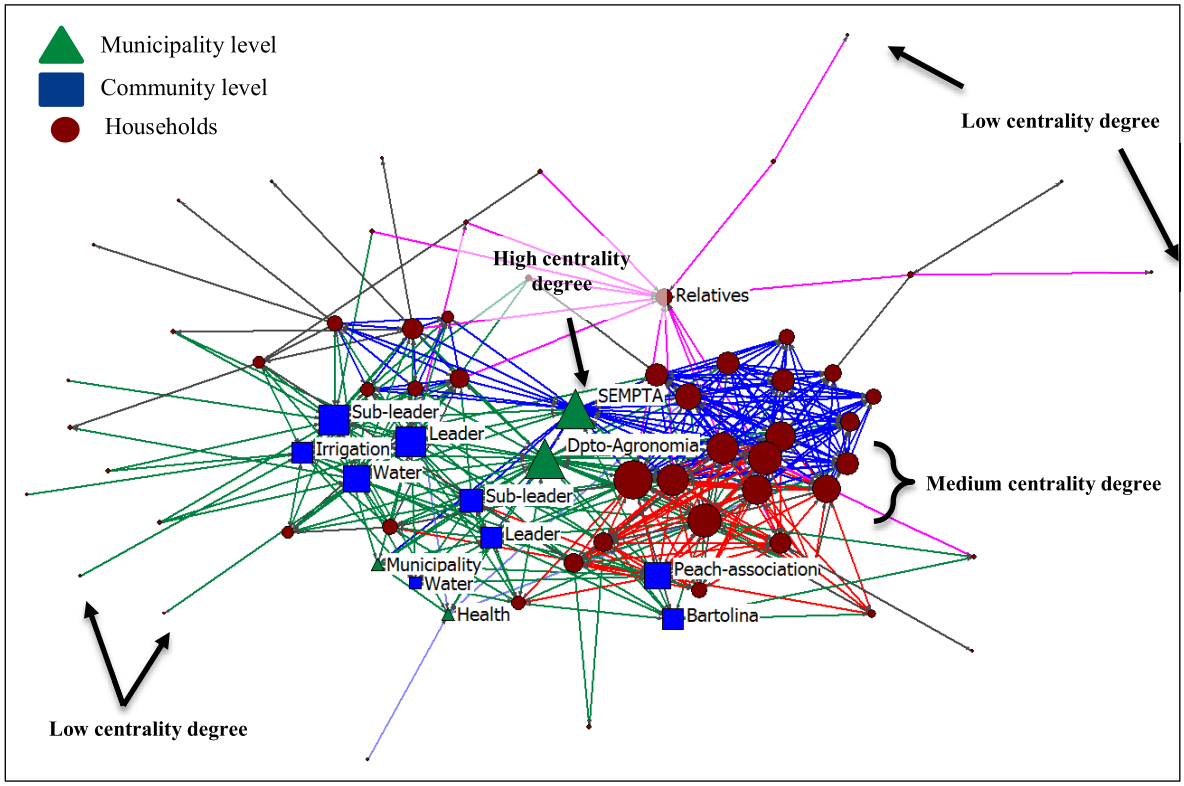


Figure 7.7: Categorization of strategies implemented in the inter-Andean valley between 72 pairs of actors to cope with socio-economic conflicts and degree centrality. Where the strategies are represented with lines (ties) in different colors: red = peach production association; dark blue = National Program of Bioculture; light violet = health care related activities; grey = agricultural production; green = organization and planning related activities,

pink = familiar relationships. The degree centrality is represented in the sociogram using different sizes of the actors' symbol; bigger size represents high degree centrality.

The function of the social network in the scenario of socio-economic conflict is diverse and complex to analyze. The recorded answers from the survey have been classified into six sets of strategies. 1) 233 pairs of actors worked together on the organization and planning-related activities. 2) 182 pairs of actors worked together on the PNB. 3) 148 pairs of actors worked together on activities related to the Peach Producers Association. 4) 32 pairs of actors shared labor for agricultural production. 5) 18 interactions between a pair of actors were based on familiar relationship. 6) Four pairs of interaction were related to health-care (Table 7. 2; Figure 7.7).

Table 7.2: Description of the strategies to cope with socio-economic conflicts, based on the interaction of 72 actors in the inter-Andean valley.

Strategy	**Description of interaction**
Organization and planning	This relationship occurred mainly among local authorities, municipality staff, and social organizations; included activities related to the development and implementation of programs and projects, budget distribution, and administration activities. More precisely:
	Relationship authority – authority: established strategies on maintenance of roads, education system, agricultural production, assignation and distribution of budget for projects, health care, and reinforcement of infrastructure.
	Relationship authority – social organization: established strategies on coordination for the implementation and control of projects related to agricultural production and gender.
	Relationship household – local authority: identified and recorded the current situation of households and the community in general.
	Relationship household – social organization: work together on the implementation of projects related to agricultural production.
	Relationship household – household: Work together in coordination with the authorities on the implementation of action plans related to agricultural production.

Continuation…

Strategy	Description of interaction
National Program of Biocultura related activities	Relationship SEMPTA – authorities: implementation of strategies based on regulations and agreements for the operation of the NPB in the community.
	Relationship household – SEMPTA: strategies centered on the transfer of knowledge, training, irrigation systems, and pest control.
	Relationship household – household: strategies centered on the participation in the program, and exchange of experiences focused on improvement of agricultural production, reinforcement of knowledge on agroecology practices, implementation of the irrigation system and reinforcement of social organization.
Peach grow association	Relationship household – household: capital investment for peach production, exchange of experiences.
	Relationship: household – authorities: local regulations and market opportunities.
Agriculture production	The relationship between households based on *minka* and *ayni*.
Familiar relationships	This relationship occurred between a local actor (household) and a relative living outside the community. The interactions between this pair of actors supported local families to cope with socio-economic conflicts. Relatives living outside the community contributed with remittances and/or temporary labor during the harvesting season.
Healthcare	This relationship is related to the need of a household for health care from the local health center.

Research own derivation based on 72 household and key informant interviews (Figure: 7.7)

7.3.2 Formation of social networks in the scenario of extreme weather events

Here, the explorative analysis of social networks described the relationship among actors, whenever an extreme weather event threatens the well-being of the families. The identified social network shows the way in which 52 actors are related to each other and displays a total of 152 interactions among them (Figure 7.8). The network has been integrated into a set of

small sub-groups, many of them integrating only households, and just one integrating with local and municipal authorities. Most of the strategies adopted by the households (if there was one) focused the attention on secure agricultural production in small sub-groups.

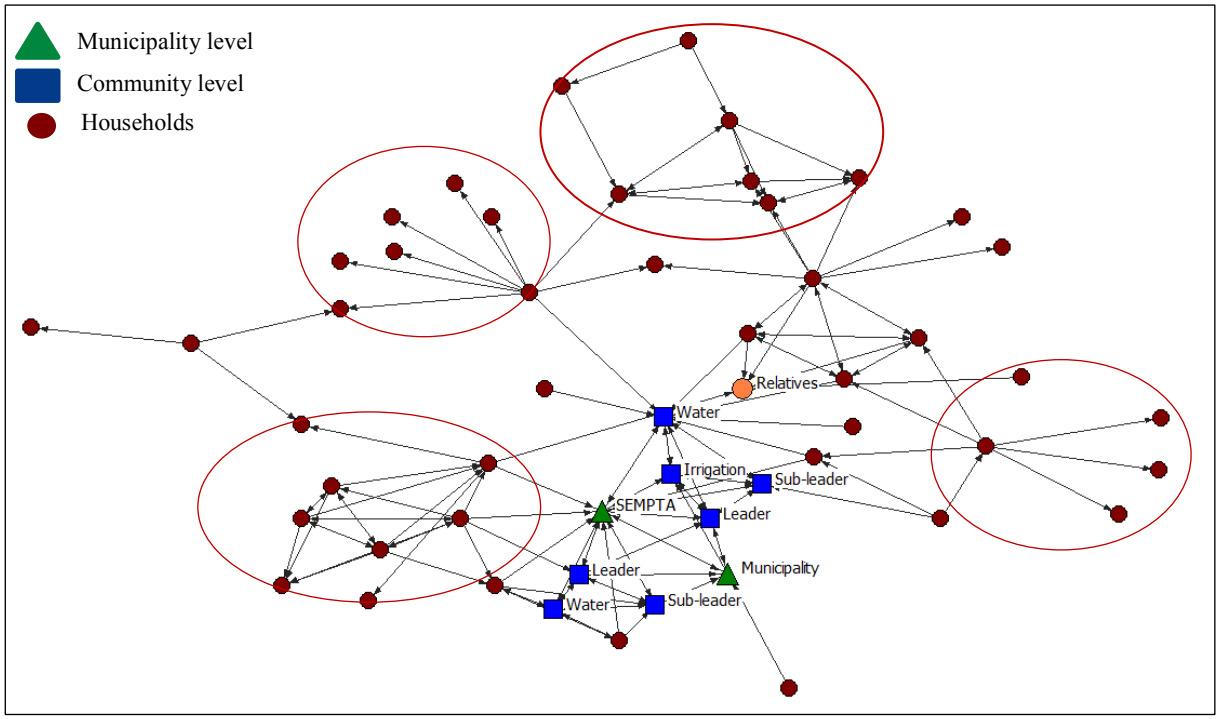


Figure 7.8: Structure of social network in the inter-Andean valley based on the interaction of 52 actors whenever extreme weather events were threating the well-being of the households.

The strategies implemented between actors to cope with extreme weather events are summarized in three main activities (Figure 7.9). 1) The relationship between 76 pairs of actors is based on agricultural production; they work together on the land by practicing in *ayni* and *minka,* and sometimes daily labor. 2) The relationship between 70 pairs of actors is based on organization and planning-related activities; these interactions occurred mainly between local authorities at the community and municipality level. They worked together on the implementation and maintenance of irrigation systems and the elaboration and implementation of a management risk plan. 3) Finally, the minority of interactions, 8 ties, were based on the economic support from relatives.

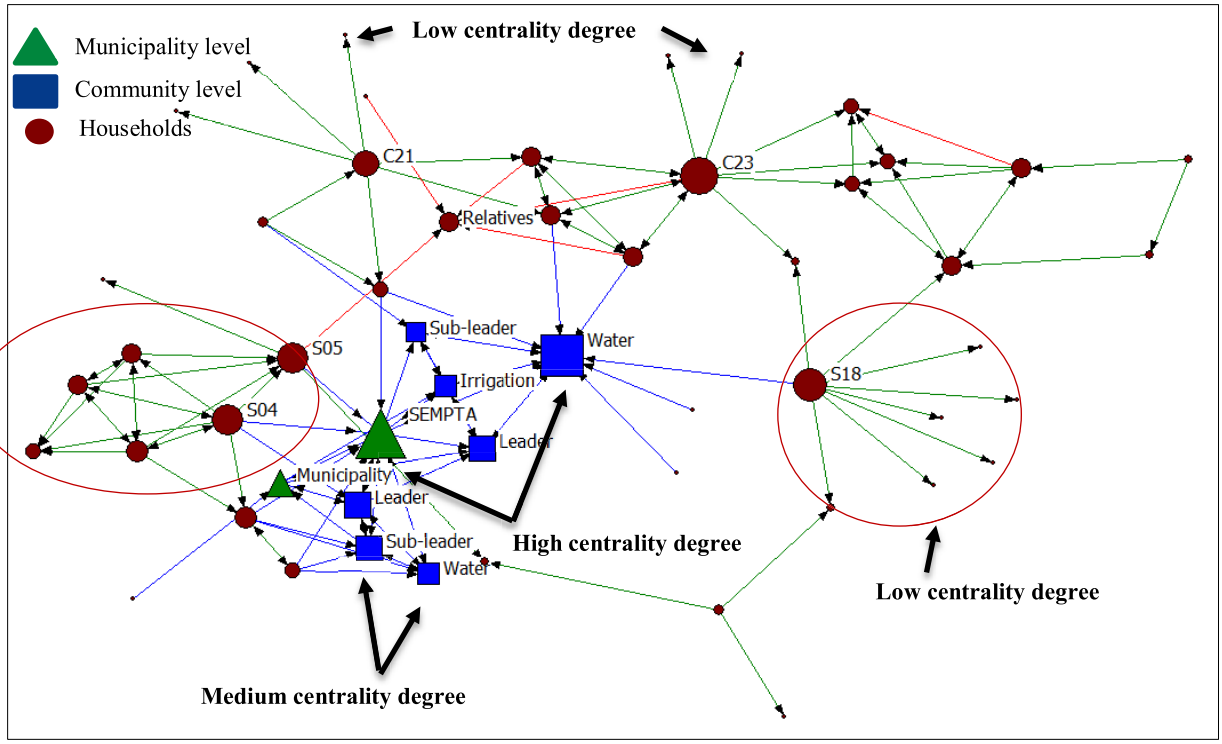


Figure7.9: Categorization of strategies implemented between 52 actors to cope with extreme weather events and degree centrality in the inter-Andean valley. Where the strategies are represented with lines (ties) in different colors: green = agricultural production related activities; blue = organization and planning related activities; red = external cooperation from relatives. The size of the actors represents the degree centrality, bigger = high degree centrality.

The centrality measure identified the authority in charge of water and SEMPTA as the actors with higher degree centrality. Both actors had an important role in the implementation of the irrigation system. In a way, these actors also present characteristics of bridging actors, facilitating the flow of resources needed for the implementation of the irrigation system. Actors located in small sub-groups showed a medium degree centrality, including households and local authorities (Figure 7.9).

7.4 Interpretation of the social network approach

7.4.1 The social network structure

The network approach presented here represents a first explorative analysis on how people in the case study communities behave in relation to a particular scenario. The first scenario

assessed the behavior of households and stakeholders in the situation of socio-economic conflicts, and the second one in extreme weather events. This approach supports understanding how an individual's interaction is determined by the social and environmental context. Based on the outcomes, the structure of social networks emerged from the daily life interaction of people in the communities and showed how households and stakeholders approach specific conflicts by assuming a combination of strategies related to agricultural production, local initiatives, organization and planning, family relationship, and health care. The interaction of people and the combination of strategies support securing the well-being of the families. As mentioned by Jakson (2010) and Burt (2000) the participation in social networks promotes the well-being of the people by endorsing access to new goods and knowledge.

The assessment of network structures has established the position of every single actor in the network, identifying sub-groups, bridging actors, and periphery actors. This assessment showed a defined pattern of interaction between households and stakeholders. For instance, relationships among households are based on family or neighbor relationships; and relationships among households and stakeholders are based on political regulations and local interests. In terms of climate change adaptation, the social network has the potential to facilitate the two-way flow of information between stakeholders: upwards from the households to improve political understanding of local socio-economic and environmental context, knowledge, and needs; and downwards from the municipality and other stakeholders to deliver relevant and current science (Ensor & Berger 2009). Therefore, the social network analysis permits a step ahead, guiding policy makers on the implementation of adaptation strategies (Morone et al. 2015, Ramirez 2013).

Every actor in the network possesses a particular pool of knowledge and resources, which can be shared with other actors depending on the position in the network (Ramirez 2013). For instance, inside a sub-group actors will share a given pool of knowledge and resources. The two-way flow of information between sub-groups of stakeholders and households is possible due to particular actors or sets of actors located in the bridging position (Isaac 2012). For climate change adaptation the flow of this knowledge and resources between sub-groups is a potential strategy to promote the well-being of the households. For instance, the identified bridging actor in the inter-Andean valley (Figure 7.6) facilitated the communication between

authorities and households, making possible the implementation of the National Program of Bioculture, in which both sub-groups contributed to the program with their own resources. Hence, the positions of the bridging actors represented an important strategy for the livelihood of other households, but also for its own good. For instance, in the highlands (Figure 7.2), the bridging actor between fishermen and ASITURSO had access to knowledge related to agro-tourism and fishing, therefore having better opportunities to face socio-economic and climate-related threats than actors located in one sub-group or in the periphery of the network (Ramirez 2013).

Actors in a periphery position are tied to fewer actors; fewer ties provide the actor with a limited opportunity to access other actors who are willing and able to be supportive, as well as fewer opportunities to take care of the other actors when they are in = need (Lee and Kim 2011). Therefore, they lose the opportunity to develop adaptive strategies in the face of emerging climate risk (Ensor and Berger 2009). As explained by Morone et al. (2015), Williams et al. (2015), Manson et al. (2014) and Righi (2013), Borgatti et al. (2009), the integration of an individual in a network is a key factor in the fostering of livelihood adaptation strategies and can affect the function and the outcomes in agricultural production.

7.4.2 The social network function in socio-economic and extreme weather event scenarios

When social networks have been formed in socio-economic scenarios, the strategies assumed by the households and stakeholders target the well-being of the families in a larger context; for instance: economic development, food security, education, organization, infrastructure, and health. Certainly, these actions are long-term planning strategies, where the two-way flow of information allows the development and monitoring of a master plan in which the municipality and other stakeholders are the main institutions for the implementation at the local level, and the households are the beneficiaries.

When social networks have been formed in scenarios of extreme weather events, the strategies assumed by the actors have been focused mainly on agricultural production (Figure 7.10). Households work in close relationship with community members to avoid losses in crop production by accessing immediate labor. It is important to consider that household networks built up after a climatic event can improve access to climate knowledge by using

influence through the network to generate climate information that is more closely related to the lives and livelihood strategies of the community (Ensor & Berger 2009). Further on, the existence of social networks in rural communities is considered as coping strategies to weather-related hazards (Adger 2003). Moreover, social networks play a primary role in adaptation and recovery when governmental intervention is absent or low, in which case the network represents the social capital that takes over as a substitute for help from the state (Ensor & Berger 2009). For instance, in the case of the highlands, when the crops were flooded, households accessed *minka* and *ayni* for harvesting and secured part of the production while they waited for the tractors from the municipality.

Independently for the case study, the assessment of social networks in a scenario of socio-economic conflicts showed that households and stakeholders have more interactions, assuming more strategies than in a scenario of extreme weather events. Based on data survey, in the highlands the number of interactions among actors whenever they faced a socio-economic conflict was higher (mean = 6.5; max = 33; min = 1) than when the actors were facing extreme weather events (mean = 3; max = 35; min = 1; Mann-Whitney U-test =-2.768; p = 0.006, Figure 7.10), and in the inter-Andean valley the same happened, where the number of interactions among the actors when they were facing a socio-economic conflict was larger (mean = 13; max = 51; min = 1) than when the actors were facing extreme weather events (mean = 4.5; max = 19; min = 1; Mann-Whitney U-test =-4.264; p = 0.000, Figure 7.11).

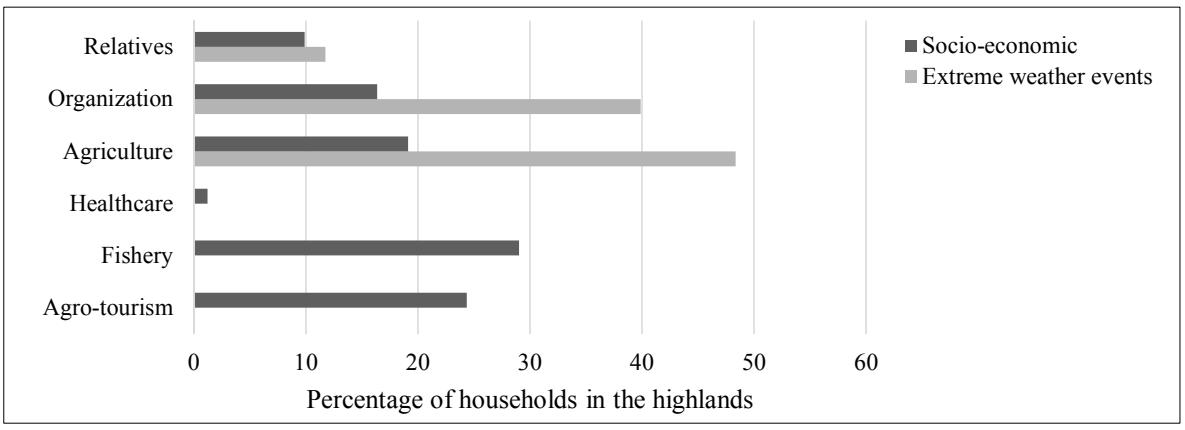


Figure 7.10: Strategies and the number of interactions among actors whenever they are facing socio-economic conflicts and extreme weather events in the highlands based on the relationship of 58 actors.

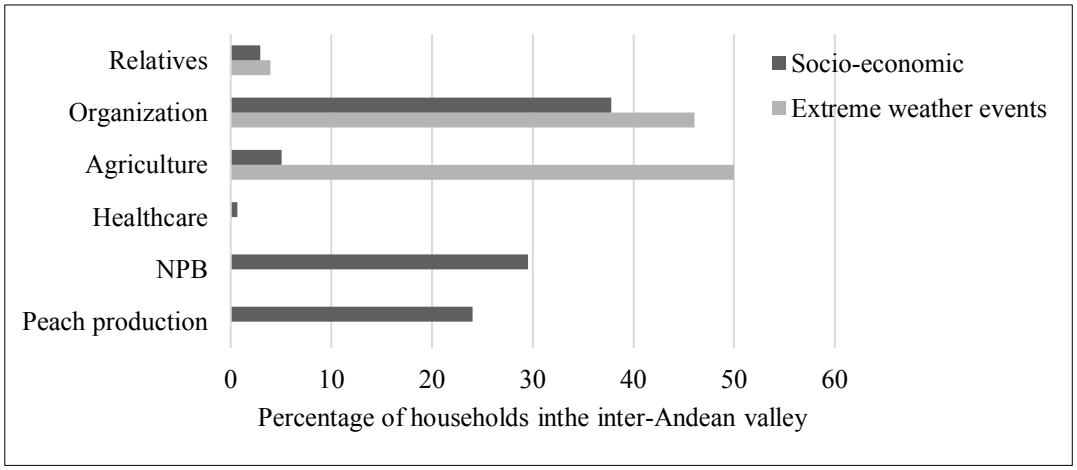


Figure 7.11: Strategies and the number of interactions among actors whenever they are facing socio-economic conflicts and extreme weather events in the inter-Andean valley based on the relationship of 72 actors.

7.4.3 The meaning of social capital and centrality measures

Social capital and degree centrality are important tools for the assessment of social networks. On one hand, social capital is defined in the network approach as the benefit that accrues to the collectivity as a result of the maintenance of positive relationships between different groups, organizational units, or hierarchical levels (Burt 2000; Kilduff and Tsai 2005). On the other hand, the assessment of degree centrality – number of interactions that one actor has – permits a step ahead in the understanding of the social capital that exists where people have a higher number of interactions and a favorable location in the network. For instance, if a farmer trades seeds with four other farmers, the degree centrality is four (Ricciardi 2015). Therefore, the assessment of degree centrality defined the social capital of a determinate actor (Hofstra et al. 2015, Sankar et al. 2015, Lee and Kim 2011). For a household, that means a potential resource, also seen as "personal investment" that could be used for economic advantages by the activation of particular links in the social network (Kilduff and Tsai 2005).

Also, certain network positions and structures related to degree centrality are indeed associated with individual performance, as is the case of bridging actors (Hofstra et al. 2015, Ramirez 2013, Ricciardi 2015). For example, the household members of the Peach Producers Association in the inter-Andean valley showed an elevated number of interactions (Figure 7.7) and consequently high degree centrality; these interactions allowed members of the association to gain knowledge on soil conservation techniques, pest management,

transformation, and storage of fruits. Another example is the role of SEMPTA on the implementation of PNB, the high number of interactions of this actor facilitated the flow of knowledge (soil management techniques, pest management) and resources (construction materials, new seeds) from outside and contributed to the flow of information among the households participating in the program. This example shows that connected populations may be better able to mobilize their resources and may be better able to bring multiple and diverse perspectives to bear to solve problems. The ability to act collectively in a community that depends on natural resources is an important determinant of local adaptation (Rodima-Taylor 2012).

As observed in the highlands, degree centrality and income of the household were positively correlated in social networks formed in a socio-economic scenario (see section 7.2.1). That means the social capital available for a particular actor has the potential to contribute to secure their livelihood. An actor located in a central position (higher degree centrality) implies that he manages a greater number of relationships with other actors, providing the actor with better and more opportunities to access others who are willing to exchange social support (Lee and Kim 2011). This is consistent with findings by Ramirez (2013) that farmers with higher degree centrality are likely to be major communication channels for the diffusion of technologies.

8. INTEGRATED MODEL FOR ADAPTIVE CAPACITY

The development of an integrated model able to explain factors that contribute to adaptive capacity is complex, especially for rural communities in the Andean region whose livelihoods are dependent upon agriculture and local resources. This model focuses the attention on high-impact indicators that have been identified during the assessment of cultural strategies (non-material assets), socio-economic strategies (material assets), and social network strategies. The integration of these elements of adaptive capacity provides a holistic view on accurate livelihood adaptation strategies that promote adaptive capacity in the communities.

8.1 Proposed model towards adaptive capacity for the case study of the highlands

As described earlier, the livelihoods of households in the highlands are affected by the changing social and climatic conditions and especially by the occurrence of extreme weather events in the last years. The proposed model documented four complexes. ***Complex I***: describes the impact of intensive rainfall, hailstorms, droughts and frost on the livelihood. Families have been affected by pest attacks, agricultural losses, reduction of water resources, and soil erosion. ***Complex II***: Proposed strategies based on the assessment of the social system, highlighting the role of cultural, socio-economic, and social network strategies defined in the *Complex III.* The proposed strategies integrated the research results with the local opinion of the households and stakeholders. ***Complex III***: documents the principal strategies identified according to the selected categories (cultural, socio-economic and social network) highlighting the potentialities and limitations of each one of them. ***Complex IV***: Livelihood adaptation strategies, are the integration of the proposed strategies with the existing adaptive capacity of the community based on the non-material assets, material assets and social network (Figure 8.1).

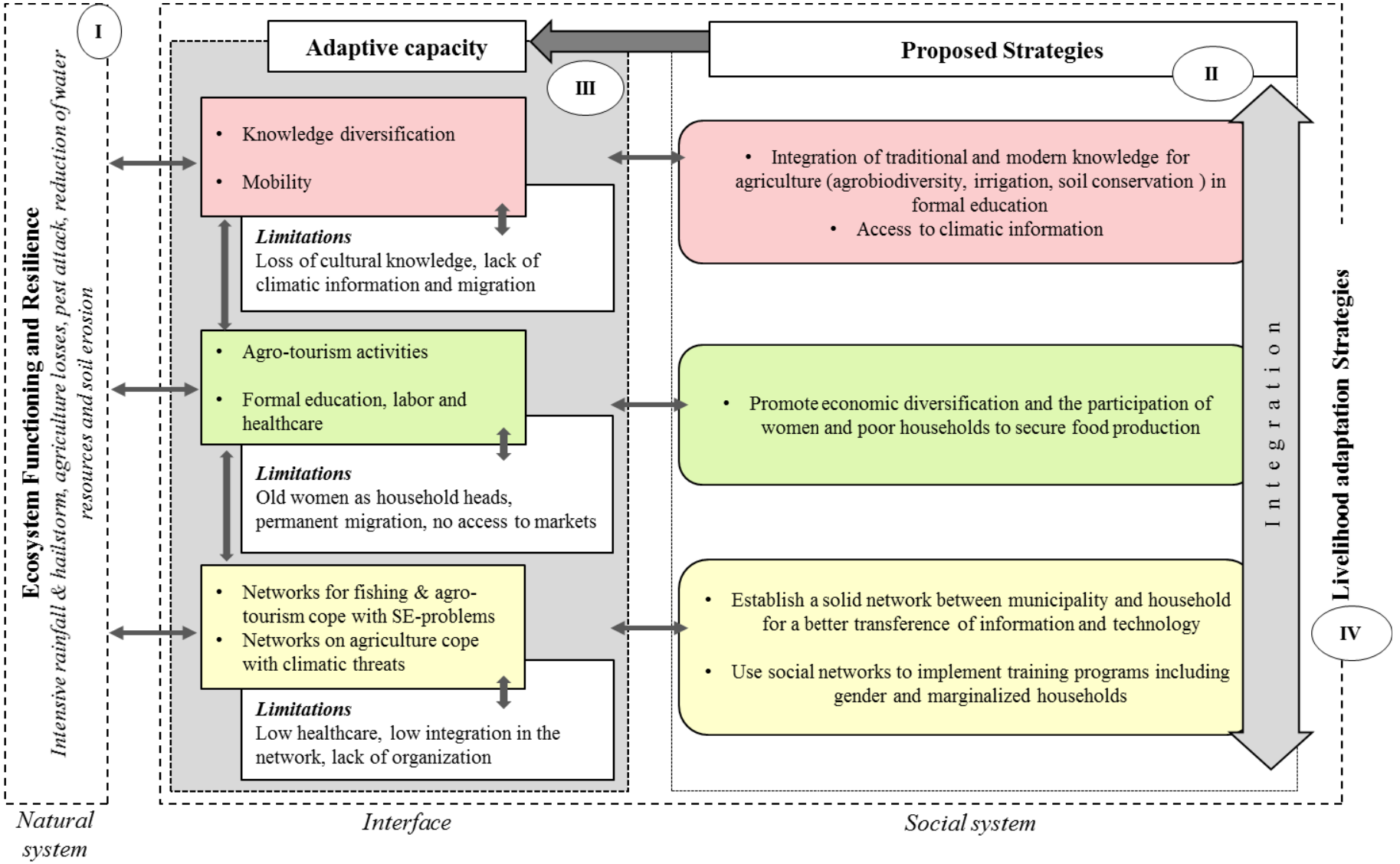


Figure 8.1: Proposed model towards adaptive capacity for the case study of the highlands.

8.1.1 Potentialities and limitations of adaptive capacity in the highlands

The assessment of cultural knowledge in the highlands highlights two important strategies: economic diversification and mobility as the main contributing factors to secure the well-being of the households. The economic diversification shows the pool of skills and knowledge of the households to develop non-agriculture-related activities. This strategy can be seen as dynamic adaptation processes created through pressures and opportunities by which rural households build a diverse portfolio of activities and assets in order to survive and improve their standard of living (Kamanga 2009). In other words, economic diversification can be also understood as knowledge diversification. Cultural strategies based on mobility stand by the ability of the household to access different markets and other resources outside the community (Matijasevic 2014).

Nevertheless, cultural strategies are limited by the erosion of traditional ecological knowledge (TEK), lack of climatic information, and permanent migration of young generations. The erosion of traditional ecological knowledge is attributed to the low rate of knowledge transfer from the older to the younger generation and the new trend of formal education which does not include TEK. This knowledge is transmitted informally during field activities rather than in formal teaching situations (Matijasevic 2014, Gilles et al. 2013). The fact that young people are going to school and then have off-farm employment mostly limits their participation in the farm and the opportunity to learn from experience. On the other hand, the lack of climatic information occurs because the traditional weather forecasting techniques are poorly understood and also because the meteorological data is not fully available. Therefore, the lack of this information prevents the implementation of accurate risk management plans to secure agricultural production reducing the possibilities for adaptation to climate change.

Migration has a significant impact on the erosion of traditional knowledge and the use of weather forecasting techniques. As explained by Armelin (2011), young people in the communities mostly drive the evolution and adaptation of knowledge during environmental and societal changes. When the younger population is absent from the communities, the organic flow of knowledge transfer breaks. Elders are not able to transfer their knowledge, and they are less receptive to learning new techniques. Therefore, the evolution of knowledge is under threat and makes elders more vulnerable to social and climatic changes. Moreover, migration from rural areas is reducing labor in the farm. As mentioned earlier, local farmers

do not have the time to observe natural phenomena to guide their agricultural practices. Lack of labor forces them to look for short-term strategies.

Income from agro-tourism activities, fishing, and off-farm activities showed to have a significant contribution to the economic diversification of the households. As mentioned earlier in Chapter 7, the income generated from these activities is re-utilized in agriculture and to maintain their lifestyle as farmers. Therefore, this strategy has the potential to contribute positively to local adaptive capacity (Rodima-Taylor 2012). Economic diversification is becoming increasingly relevant as a local strategy to face both climate variability and local poverty. Nevertheless, not all the households have the resources needed to implement these strategies. The identification of poor households points out that old women living alone and with limited access to the market are the most vulnerable group. The issues of social inclusion and gender are promoting the local climate vulnerability of marginalized groups. On the other hand, for the wealthy households the access to formal education, labor availability, and health conditions are the drivers for economic diversification, mainly off-farm, agro-tourism, and fishing; therefore, wealthy households have better opportunities to adapt to changing conditions. But special attention is needed when proposing fishing and off-farm activities, and before that happens, a full assessment of the sustainability of these activities must be done.

Social networks in a scenario of socio-economic conflict contributed to the development of agro-tourism activities and fishing. The households that have participated in these activities also showed better rates of income and the highest number of interactions, suggesting that these actors have better access to social capital by working in groups and interacting with other actors in the network (households, social organizations and authorities). Moreover, these activities are long-term strategies with the potential to support the overall well-being of the families. The formation of social networks in the scenario of extreme weather events contributed to secure food production. Farmers cooperated with each other as labor exchange during or after the impact of an extreme weather event. Therefore, agricultural losses can be reduced. Once more, poor households, older women, and sick people as the marginalized groups in the community are not well-integrated in the social networks, and therefore they are the most vulnerable to the impact of extreme weather events.

8.1.2 Livelihood adaptation strategies proposed to boost adaptive capacity

The identification of livelihood adaptation strategies based on limitations and potentialities of the interface of the system (Figure 8.1) shows the need for guidelines to replicate those strategies that support the well-being of the households and reduce the limitations which break the process of adaptation to current social and climatic changes. Therefore, the following livelihood adaptation strategies have been identified:

Integration of traditional ecological knowledge in formal education complemented with new techniques and technologies: It is essential to provide communities with an adequate education system which respects and promotes TKE. This knowledge has the potential to contribute to the conservation of local agrobiodiversity (e.g. diversification of tubers) and adequate management of water and soil resources. The integration of this knowledge in the formal education has great potential to reinforce and revalidate the ancient knowledge with scientific bases, respect traditional systems, and integrate new techniques and technologies that are suitable for the current scenario in the communities (LIDEMA2010). This strategy requires investment from the governments or development agencies in mechanisms that replace traditional ways of transmitting knowledge – especially in ways that strengthen and create farmer-to-farmer networks of communication, respecting the cultural vision of local people.

Weather forecasting information: It is essential for farmers to access updated and accurate climatic information which supports the decision-making related to agricultural activities. This information contributes to the development and implementation of risk management plans to cope with extreme weather events. On one hand, early warning systems with meteorological information will require investment and participation of government and other institutions. On the other hand, the use of traditional weather forecasting indicators demands a significant amount of time to change production strategies in response to their predictions. Therefore, the use of traditional indicators must be complemented with meteorological data. Yet is important to promote validation and integration of indicators to the early warning system to have a better impact on local families and the use of this information. Promoting this strategy must be done together with strategies to reduce migration, as is a contributing factor for the loss of traditional ecological knowledge.

Promote economic diversification to allow households to secure food production with emphasis on gender and young generations: The development of economic diversification should be focused on out-farm activities with the potential to contribute to the overall well-being of the household. In this way, agriculture can be complemented by activities related to agro-tourism, manufacturing, handicrafts, services, pre-industrialization processes, etc., in order to promote local development respecting cultural beliefs and customs. The inclusion of this knowledge and these resources for women and young generation reduces the vulnerability of poor and marginalized households and is a strategy to attract young people, preventing migration away from the community.

Establish a solid network between municipality and households for a better transfer of information and technologies: Networks between municipality and households provide the municipality with updated information of the current situation in the communities and the households with climatic information and technologies to support the development of sustainable agriculture. Therefore, it is important to promote the reinforcement of current linkages between households and stakeholders from outside their communities

Use social networks to implement training programs including gender and marginalized households: The inclusion of gender and marginalized households in social networks for training is an essential tool to reduce the vulnerability of the poor households. The implementation of these strategies has to go hand in hand with the vision of endogenous sustainable development proposed by Delgado et al. (2010), respecting the local culture and customs to guarantee its functionality.

8.2 Proposed model towards adaptive capacity for the case study of the inter-Andean valley

As described earlier, the livelihoods of households in the inter-Andean valley are affected by the changing social and climatic conditions and especially by the occurrence of extreme weather events in the last years. The proposed model documented four complexes. ***Complex I***: Families have been affected by the impact of prolonged drought seasons, intensive rainfall, strong wind, and hailstorms with direct consequences for pest attacks, agricultural losses, reduction of water resources, and soil erosion. ***Complex II***: Proposed strategies based on the assessment of the social system, highlighting the role of cultural, socio-economic and social network strategies defined in C*omplex III.* The proposed strategies integrated the research results with the local opinion of the households and stakeholders. ***Complex III***: documents the principal strategies identified according to the selected categories (cultural, socio-economic and social network) highlighting the potentialities and limitations of each one of them. ***Complex IV***: Livelihood adaptation strategies are the integration of the proposed strategies with the existing adaptive capacity of the community based on the non-material assets, material assets and social network (Figure 8.2).

8.2.1 Potentialities and limitations of adaptive capacity in the inter-Andean valley

The assessment of cultural strategies highlights the importance of social-pooling, mobility, and selection of agricultural techniques as the main drivers for adaptive capacity. Households that have more access to social-pooling have had more chances to cope with extreme weather events and secure their production; social-pooling involves the sharing of wealth, labor, or income from particular activities across households and moreover contributes to the sharing of information related to market conditions (Rodima-Taylor 2012). The role of social-pooling is limited by the lack of traditional ecological knowledge related to soil conservation techniques and the high rates of permanent migration.

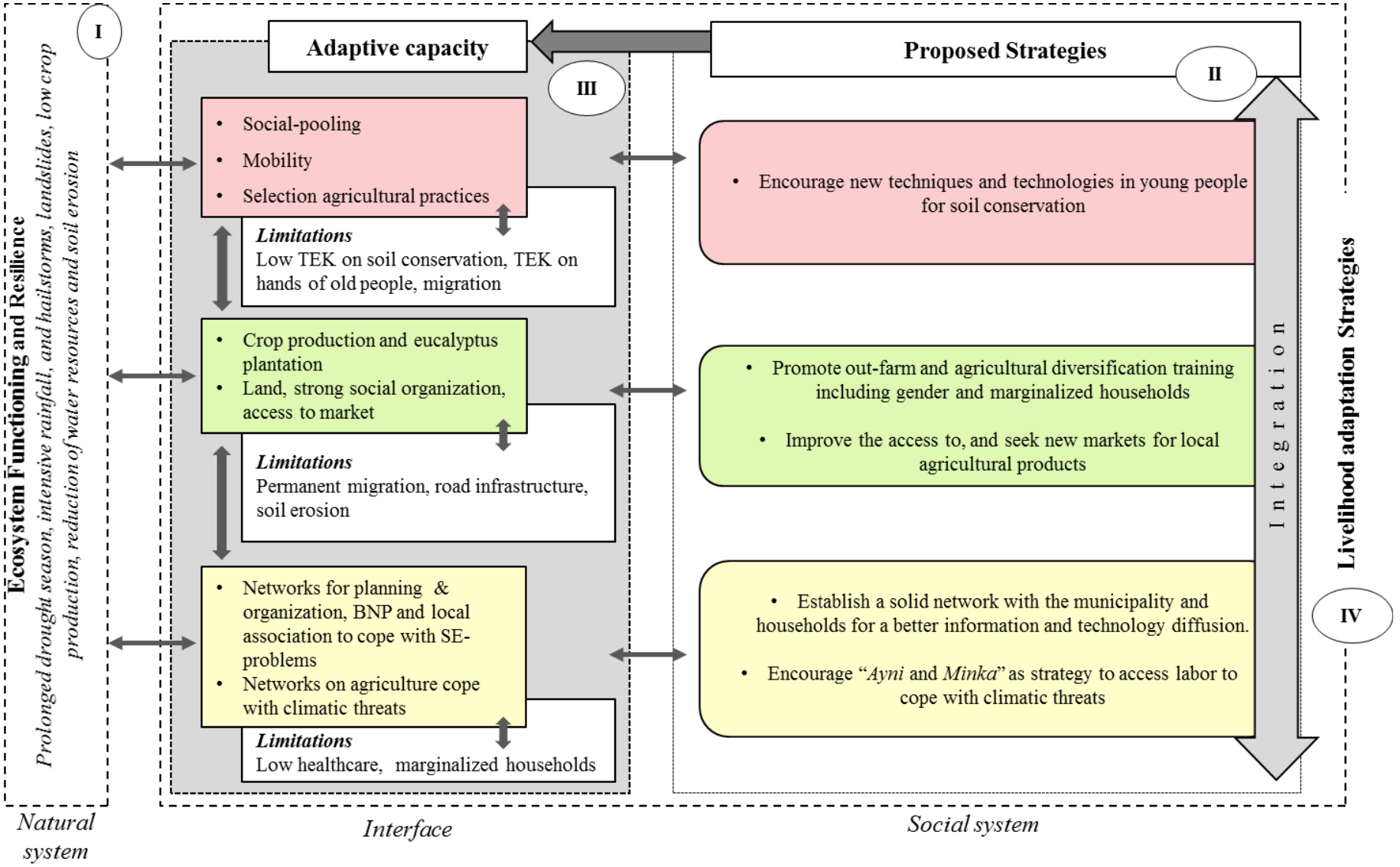


Figure 8.2: Proposed model towards adaptive capacity for the case study of the inter-Andean valley.

Mobility is a strategy that contributes the most when households have the opportunity to travel to neighboring communities for short periods of time and work in different farms. The knowledge gained during this activity and the income generated are used to improve their own farm system and secure crop production. The selection of agricultural practices is a strategy that contributes to farmers sharing new techniques and/or technologies that allow them to improve soil conservation techniques, highlighting the willingness of farmers to incorporate new knowledge and resources to improve the existing crop production. The incorporation or adoption of new knowledge in agriculture represents the evidence on which traditional ecological knowledge is a dynamic process of change and is related to nature and social changes over the time. Moreover, this strategy is closely related to social-pooling as it allows the flow of knowledge among actors in the network (Isaac 2012).

Socio-economic strategies that increase adaptive capacity in the inter-Andean valley are related to crop production and eucalyptus plantations. Here, agricultural production has great potential to lead rural development, as this activity is strongly supported by the existing social networks in the area and the access to markets. The use of eucalyptus plantations contributed significantly to the total income of the households and has the function of insurance; farmers use this resource in times of low crop production or when there is a need for immediate cash in the family. Nevertheless, the implementation of socio-economic strategies is limited by permanent migration and for poor households.

Social networks in the scenario of socio-economic conflict contributed to the implementation of long-term strategies on agricultural production, health, education, and infrastructure for households that have participated in local initiatives, e.g. the National Program of Bioculture and Peach Producers Association. This strategy increases social capital and allows the diffusion of information and the subsequent adoption of innovative and sustainable practices in agricultural technologies (Isaac 2012). Social networks in the scenario of extreme weather events support agricultural production. This strategy depends on the ability of individuals and communities to act collectively in the face of risk and can replace the intervention of the state (Adger 2003). Moreover, this strategy is also an insurance strategy based on reciprocity in times of need (Enso and Berger 2009). Strategies based on social networks limited the participation of marginalized groups in the community, making them more vulnerable to climate and social changes.

8.2.2 Livelihood adaptation strategies proposed to boost adaptive capacity

The identification of livelihood adaptation strategies based on limitations and potentialities of the interface of the system (Figure 8.2) shows the need for guidelines to replicate those strategies that support the well-being of the households and reduce the limitations which stop the process of adaptation to current social and climatic changes. Therefore, the following livelihood adaptation strategies have been identified:

Encourage new techniques and technologies for soil conservation with emphasis on the participation of young people: This strategy will provide incentives to young people to stay in the communities and will lead to new agricultural practices that also support soil conservation. This practice could be integrated into the school curriculum focused on traditional ecological knowledge. Moreover, this strategy has the potential to improve sustainable agriculture, respecting local customs and traditions, giving power to the culture and local knowledge joined with external financial assistance.

Promote out-farm and agricultural diversification training including gender and marginalized households: Group activities are constituted as an important vehicle for economic advancement for marginal social categories, such as women and youth (Rodima-Taylor 2012). In addition, women have the potential to develop different activities and are open to new knowledge; therefore, this strategy has the potential to enable vulnerable households to leave the condition of poverty.

Improve the access to, and seek new markets for local agricultural products: Access to markets provides household the opportunity to diversify the available resources and provide food security in the household. Therefore, the maintenance and improvement of roads contribute to reducing the vulnerability of the households.

Establish a solid foundation for the network with the municipality for better information and technology diffusion: The development of adaptive capacities demands current climatic information that contributes to better anticipate than to react to an event, making the risk management plans more efficient. This plan can be developed in a network between municipality and households. The network provides the municipality with updated

information on the current situation in the communities and the households with climatic information and technologies to support the development of sustainable agriculture.

Encourage "ayni and minka" as strategies to access labor to cope with extreme weather events: In social networks, climate information and adaptation resources are articulated (Ensor and Berger 2009). Networks based on *"ayni and minka"* represent the social capital that provides immediate labor to households when needed. Strategies rooted in the cultural characteristics of daily life in the communities have the potential for a better impact on the process of adaptation (Delgado et al. 2010).

8.3 Synergies and constraints in both case studies

The proposed models for adaptive capacity presented here have particular characteristics according to the case study. Besides the bio-physical and social differences between the two eco-regions; cultural, socio-economic and network strategies presented common patterns. In both case studies it has been observed that poverty, migration, erosion of traditional knowledge, lack of climate information, age and gender are the key factors that limited the adaptive capacity. After the occurrence of extreme weather events, the poorest households are the worst hit, making them the most vulnerable to climate change because they have few assets and little to fall back on after a shock event which calls for resources to address it. It is the disproportionate impact on poor people that makes climate change an issue for development (Enso &Berger 2009). Identification of poverty indicators in the case study contributed to the understanding of the overall vulnerability of the households (Skjeflo 2013). Moreover, appropriate adaptation measures can be developed and implemented.

Therefore, rural communities are the perfect example to illustrate that adaptation is a process, in which adaptive capacity is an ongoing learning and dynamic system, where planning and adjustment are required to respond to the evolving context of social and climatic changes. It also requires new knowledge and information, as well as provision and access to diverse socio-economic resources accessible also to the most vulnerable groups. In farming communities, the successful adaptation of agriculture to climate change will depend ultimately on the actions of individual farmers and their flexibility in applying new management strategies (Kalaugher et al. 2013, Mendelsohn and Dinar 2009). Moreover,

adaptive capacity is shaped fundamentally by people's everyday activities with respect to their adopting (or not) environmentally responsible behaviors, and whether (or not) they think adopting such behaviors might reduce their risk exposure (Jones and Clark 2013).

9. FINAL REFLECTIONS AND RECOMMENDATIONS

9.1 Lessons learned and critical reflections

This research presents evidence on how social and climate change are the major contributing factors to the increasing vulnerability of the socio-ecological systems in two case studies: the highlands and inter-Andean valley. Based on the assessment of cultural, socio-economic, and social network strategies, the outcomes contributes to the understanding of adaptive capacity to climate and social changes in rural communities whose livelihoods are dependent upon agriculture and local resources. Based on data survey, people from the highlands and inter-Andean valley are challenged by the occurrence of extreme weather events and socio-economic changes. Yet, it has been recorded a wide set of adaptation measurements that people is using in their daily life to secure the well – being of the households based on the access and ownership of knowledge, information, and resources.

The assessment of cultural strategies showed that the Andean people, regardless of the region where they live – highlands or inter-Andean valley – base their livelihood adaptation strategies on the traditional ecological knowledge of their surrounding environment. The conclusion derived from this chapter can be summarized in three points: 1) Performance of rituals, transfer of knowledge from old generation to new generation, and the use of indicators for weather forecasting have been performed by less than 50% of the population; yet these strategies showed no direct relation to crop production. This situation is a warning of the potential loss of traditional ecological knowledge, but also indicates that this knowledge has become less useful over time. 2) The storage and selection of agricultural practices in the communities represented the willingness of the households to incorporate new knowledge to improve their quality of life and secure food production. 3) Finally, economic diversification in the highlands, social-pooling and mobility in the inter-Andean valley could be considered as strategies with a great potential to secure crop production in the climatic stress scenario. These strategies anticipate change and spread risk over space and time.

The assessment of socio-economic strategies showed that the poor households are the most vulnerable group to social and climate change due to their limited livelihood resources, in particular, human and social resources; this group included old women in charge of the farm living alone in the community. Moreover, in the highlands, out-farm activities represented a

potential strategy whenever the crop production is reduced or limited; these activities were related to the labor availability in the household, health conditions, and level of education. In the inter-Andean valley, out-farm and eucalyptus plantations represented a potential strategy to secure crop production when households had access to land and markets and they participated in social networks.

The assessment of social networks presented a first explorative analysis on the behavior of social networks in two scenarios: socio-economic conflicts and extreme weather events. Independent of each case study, when households were facing socio-economic conflicts, the social networks were complex and focused the attention on a wide range of long-term strategies to secure the overall well-being of the households; for example implementation of projects for rural development including health, education, infrastructure, and agriculture. When households experienced extreme weather events, the social network focused the attention on labor for agriculture to secure crop production in a short time. The role of authorities was to establish agreements of cooperation; for example on the implementation of community works for the canalization of rivers or maintenance of communal roads. Moreover, to some extent, the measurement of degree centrality showed a positive correlation with income, a finding which indicates that the more connected the household is, the better support it will get to cope with and adapt to a particular situation.

Therefore, the proposed model towards adaptive capacity is a tool that can be used to guide new policies and programs that target poverty reduction and minimize the adverse impacts of climate change for poor people, not only in the case studies but also in neighboring communities under similar characteristics. Based on the information presented here, the model towards adaptive capacity is a complementary tool to the integral community management "*Gestión comunitaria*" (in Spanish, Delgado et al 2010). The proposed strategies in the model respect the local culture and the traditional customs of the people and have the potential of a greater acceptance among the community and therefore greater impact on household welfare (Ziche and Rist 2001). Finally the model follows the recommendation of Delgado et al. (2010) on endogenous sustainable development where highlights that the implementation of programs on social and climate change adaptation in the communities must necessarily be comprehensive and holistic, contemplating the three dimensions of everyday life in the communities: human, natural, and spiritual.

9.2 Outlook

This research extends the knowledge on how livelihood adaptation strategies can contribute to climate change adaptation and suggest general guidelines for building adaptive capacity based on data survey and local perspective. Through the research of the two case studies, the proposed models towards adaptive capacity included:

For the highlands

- Cultural knowledge is developing according to the needs of local households; there is a necessity for complementation of traditional ecological knowledge with new accurate knowledge that supports the development of sustainable agriculture.

- Poor households are the most vulnerable to social and climate changes. This group is mainly integrated by older women living alone in the communities in charge of the farm and care of the family. Therefore, it is important to promote economic diversification based on out-farm activities with emphasis on gender and age.

- Social networks in the scenario of socio-economic conflict contributed to the development of agro-tourism activities and fishing. Households that have participated in these activities were better integrated into the networks and showed better income.

- Social networks in the scenario of extreme weather events enabled immediate access to labor to secure food production. Moreover, they provided the municipality with updated information of the current situation in the communities and the households with climatic information and technologies to support the development of sustainable agriculture.

For the inter-Andean valley

- The occurrence of extreme weather events such as prolonged drought seasons, intensive rainfall, and hailstorms had a significant impact on agricultural production; nevertheless, households were able to dedicate all year round to this activity due to the friendly conditions of the landscape.

- Sustainable agriculture and forest management are the potential strategies to cope with social and climate changes. The implementation of these activities is limited by low soil conservation techniques, poverty, and permanent migration.

- Social-pooling was the main strategy that contributed to the ability of households from the inter-Andean valley to secure food production.

- Social networks in the scenario of socio-economic conflict support the implementation of long-term strategies to support the overall well-being of the households. Adaptation strategies need to focus the attention on the integration of marginalized individuals.

- Social networks in the scenario of extreme weather events enabled immediate access to labor to secure food production. Moreover, they provided the municipality with updated information on the current situation in the communities and the households with climatic information and technologies to support the development of sustainable agriculture.

9.3 Limitations of the research and suggestions for further extension

The methodology applied during the research provides a significant qualitative and quantitative set of data, appropriate for describing the current socio-economic and climatic context in the communities and analyzing the livelihood adaptation strategies at the household level. Nevertheless, the information gained represents a static picture of the present times, as the collected data do not make a comparison over time with previous years, and do not project further scenarios through predictive models. Therefore, future research on modeling of scenarios will be highly recommended to add value to the present results.

A significant number of variables has been assessed during the research in a small number of households. However, the number of households represented the 30% of the total population in both case studies. Nevertheless, for a better understanding of the situation in both case studies, the research can be replicated in a major number of communities per eco-region, taking into consideration that some variables and measures must be adapted to the local context.

In Bolivia, the selection of indicators to assess traditional ecological knowledge is developing. Therefore, the selected indicators to measure cultural strategies are based on a literature review of the traditional ecological knowledge in different countries (China, Canada, Australia, and Nepal) and adapted to the local context of the Andean people. The assessment of cultural indicators is the first quantitative analysis developed for the study areas and contributes to the understanding of the current situation of the existing knowledge in the rural communities. During the assessment, a ranking system has been used based on the experiences of the households to measure the contribution of traditional ecological knowledge on crop production. This index integrated seven major categories, and each one of them is measured by a set of sub-categories. This index is a potential tool to assess traditional ecological knowledge. The outcomes clearly reflect the current situation, but the replication of the index in a different context must be carefully assessed and must integrate local characteristics of the study area.

For future assessments of cultural knowledge, migration should be considered as a major category. The assessment of migration in this study is based on the number of household members that have migrated permanently or temporarily. Therefore, a complementary research on current migration patterns will contribute to the understanding of the dynamic of the population and the role of migration on climate change adaptation.

The assessment of socio-economic strategies presented valuable information on the wealth distribution among the households, identified the groups most vulnerable to social and climatic changes, and assessed economic diversification. Nevertheless, the results of both case studies show the situation during the research. A comparative analysis for longer periods of time is recommended for future research in order to identify patterns that guide the diversification of economic activities to anticipate risk and reduce the vulnerability of the social system.

The social network analysis represented a valuable tool to understand the social capital of the households and to identify the strategies assumed in the network. Moreover, this information provides guidelines for the policy makers. Nevertheless, the structure and function of a network remain poorly understood, as at the moment, there is no local research to compare the findings. A limitation of this research lies in the size of the sample. It is recommended to

explore further and expand the data set to the total population in the communities. Another limitation was the lack of information related to the strength of the ties between actors. The vague of actors' answers during the interviews in terms of interactions frequency was difficult to quantify and therefore was taken out of the analysis.

10. BIBLIOGRAPHY

Adger W. Neil, 2003. Social Capital, Collective Action, and Adaptation to Climate Change. Economic Geography 79 (4):387–404.

Adger W. Neil, 2006. Vulnerability. Global Environmental Change 16 (3):268–281.

Adger W. Neil, Vincent Katharine, 2005. Uncertainty in adaptive capacity. Comptes Rendus Geoscience 337 (4): 399–410.

Agurto Adrianzén M., 2014. Social Capital and Improved Stoves Usage Decisions in the Northern Peruvian Andes. World Development 54: 1–17.

Alary V., Corniaux C., Gautier D., 2011. Livestock's Contribution to Poverty Alleviation: How to Measure It?. World Development 39 (9):1638–1648.

Ansoms A., McKay A., 2010. A quantitative analysis of poverty and livelihood profiles: The case of rural Rwanda. Food Policy 35 (6):584–598.

Arana I., Garcia M., Aparicio M., 2007. El Cambio Climático en Bolivia. Análisis, síntesis de impactos y adaptación. Ministerio de Planificación del Desarrollo, Viceministerio de Planificación Territorial y Ambiental, Programa Nacional de Cambios Climáticos Bolivia: Quality, SRL.

Arana Pardo I., Garcia M., Aparicio M., 2007. El Cambio Climatico en Bolivia. Analisis, sintesis de impactos y adaptación. La Paz: Quality, SRL.

Armellin M., 2011. Ciencia Moderna y conocimientos tradicionales en la adaptación al cambio climático. En FAO 2011. Taller internacional, Experiencias exitosas de gestión de riesgos de desastres del sector agropecuario para la adaptación al cambio climático. Impresiones Punto de Encuentro La Paz.

Barrett C., Reardon T., Webb P., 2001. Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics, and policy implications. Food Policy 26 (2001):315–331.

BID - Banco Interamericano de Desarrollo, 2014. La economía del cambio climático en el Estado Plurinacional de Bolivia 2014. Banco Interamericano de Desarrollo y Naciones Unidas. Comisión Económica para América Latína y el Caribe. Bolivia.

BioAndes, 2009. Evaluación externa del Programa Regional BioAndes en Bolivia, Perú y Ecuador. Agencia Suiza para el Desarrollo y la Cooperación COSUDE. State Secretariat fur Economic Affairs SECO. La Paz.

Boillat S.P., Berkes F., 2013. Perception and interpretation of climate change among quechua farmers of Bolivia: Indigenous knowledge as a resource for adaptive capacity. Ecology and Society 18 (4): 21.

Borgatti S.P., 2002. NetDraw Network Visualization. Analytic technologies: Harvard, MA.

Borgatti S.P., Ajay M., Brass d., Labianca G., 2009. Network analysis in the social sciences. SCIENCE 323: 892–895.

Borgatti S.P., Everett M.G., Freeman L.C., 2002. UCINET for Windows: Software for Social Network Analysis. Analytic technologies, Harvard, MA.

Burt, 2000. The network structure of social capital. Research in organizational behavior 22: 345–423.

CARE, 2011. Understanding vulnerability to climate change, insights from Application of CARE's climate vulnerability and Capacity analysis (CVCA) methodology. Poverty, Environment and Climate Change Network (PECCN). http://www.careclimatechange.org/files/adaptation/CARE_Understanding_Vulnerability.pdf. (12.04.2012)

Cochrane P., 2006. Exploring cultural capital and its importance in sustainable development. Ecological Economics 57: 318–330.

Copestake J., Dasgupta A., Baschieri A., 2010. Vulnerability to climate change in rural Ghana: Mainstreaming climate change in poverty-reduction strategies. Journal of International Development. 22 (6): 803–820.

Dazé A., Kaia A., Ehrhart C., 2009. Climate Vulnerability and Capacity Analysis- handbook. Edited by CARE-International: http://www.careclimatechange.org. (20.10.2012)

Delgado F., Rist S., Escobar C., 2010. El desarrollo endógeno sustentable como interfaz para implementar el vivir bien en una gestión pública boliviana. Primera Edicion. AGRUCO-CAPTURED: Plural Editires 61 pp. .

Ellis F., 2000. The determinants of rural livelihood diversification in developing countries. Journal of Agricultural Economics 51(2): 289-302.

Ellis F., 1999. Rural livelihood diversity in developing countries: evidence and policy implications. Overseas Development Institute. DFID Department for International Development.

Engle Nathan L., 2011. Adaptive capacity and its assessment. Global Environmental Change 21 (2): 647–656.

Ensor J., Berger R., 2009. Understanding climate change adaptation. Lessons from community-based approaches. Practical Action Publishing Ltd. 192 pp. Schumacher Center for technology and development Bourton on Dunsmore, Rugby. Eriksen S., Selboe E., 2012. The social organization of adaptation to climate variability and global change: The case of a mountain farming community in Norway. Applied Geography 33: 159–167.

Fang Y., Fan J., Shen M., Song M., 2014. Sensitivity of livelihood strategy to livelihood capital in mountain areas: Empirical analysis based on different settlements in the upper reaches of the Minjiang River, China. Ecological Indicators 38: 225–235.

Fankhauser S., McDermott T.K.J., 2014. Understanding the adaptation deficit: Why are poor countries more vulnerable to climate events than rich countries?. Global Environmental Change 27: 9–18.

FAO, 2011. Taller internacional, experiencias exitosas de gestion de riesgos de desastres del sector agropecuario para la adaptación al cambio climático. Impresiones Punto de Encuentro 344 pp. La Paz.

Fischer G., Shah M., van Velthuizen H., 2002. Climate Change and Agricultural Vulnerability. Prepared by the International Institute for Applied Systems Analysis Publications Department. Remaprint, Vienna.

Füssel H., 2007. Vulnerability: A generally applicable conceptual framework for climate change research. Global Environmental Change 17 (2): 155–167.

Gaceta Oficial del Estado Plurinacional de Bolivia, 2012. Ley Nr. 300 Ley del 15 de Octubre del 2012. Ley marco de la Madre Tierra y el Desarrollo Integral para el Vivir Bien. Edición Nr. 0431. La Paz.

Gentle P., Maraseni T., 2012. Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. Environmental Science and Policy 21: 24–34.

Gilles J., Thomas J., Valdivia C., Yucra E., 2013. Laggards of Leaders: Conservers of Traditional Agricultural knowledge in Bolivia. Rural Sociology 78 (1): 51–74.

Gómez-Baggethun E., Corbera E., Reyes-García V., 2013. Traditional Ecological Knowledge and Global Environmental Change: Research findings and policy implications. Ecology and Society 18 (4): 72–80.

Gutiérrez J. L., 2011. Unidad temática II. La Vulnerabilidad y los Impactos del Cambio Climático. LIDEMA (Ed.) Manual de capacitación en modelos integrales de intervención para la adaptación al cambio climático. LIDEMA, La Paz.

Hanselman B., William D., Gosling A., Knox C., Baker P., Fritz S., 2011. A 370,000-year record of vegetation and fire history around Lake Titicaca (Bolivia/Peru). Palaeogeography, Palaeoclimatology, Palaeoecology 305 (2011): 201–214.

Hofstra B., Corten R., Buskens V., 2015. Learning in social networks: Selecting profitable choices among alternatives of uncertain profitability in various networks. Social Networks 43: 100–112.

Hughes S., Yau A., Max L., Petrovic N., Davenport F., Marshall M., 2012. A framework to assess national level vulnerability from the perspective of food security: The case of coral reef fisheries. Environmental Science and Policy 23: 95–108.

Ibisch P.L., Mérida G., (eds.), 2003. Biodiversidad: La riqueza de Bolivia. Estado de conocimiento y conservación. Ministerio de Desarrollo Sostenible. Editorial FAN, Santa Cruz de la Sierra.

INE - Instituto Nacional de Estadística de Bolivia, 2013. Bolivia: Resultados del "Censo de Población y Vivienda – 2012. http://www.ine.gob.bo:8081/censo2012/ (13.8.2014)

IPCC, 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change Houghton J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai K.

Isaac M. E., 2012. Agricultural information exchange and organizational ties: The effect of network topology on managing agrodiversity. Agricultural Systems 109: 9–15.

Jackson M.O., 2010. Social and Economic network. Princenton University Press.

Jiménez Elizabeth, 2013. Cambio climático y adaptación en el Altiplano Boliviano. CIDES – UMSA. Plural Editorial. 255 pp La Paz.

Jones N., Clark J.R.A., 2013. Social capital and climate change mitigation in coastal areas: A review of current debates and identification of future research directions. Ocean and Coastal Management 80: 12–19.

Kadushin C., 2004. Introduction to social network theory. Chapter 2: Some basic network concepts and propositions. 60 pp. http://www.cin.ufpe.br/~rbcp/taia/Kadushin_Concepts.pdf (14.4.2013)

Kalaugher E., Bornman J., Clark A., Beukes P., 2013. An integrated biophysical and socio-economic framework for analysis of climate change adaptation strategies: The case of a New Zealand dairy farming system. Environmental Modelling and Software 39: 176–187.

Kallis G., Norgaard R., 2010. Co-evolutionary ecological economics. Ecological Economics 69 (4): 690–699.

Kamanga P., Vedeld P., Sjaastad E., 2009. Forest incomes and rural livelihoods in Chiradzulu District, Malawi. Ecological Economics 68 (3): 613–624.

Kilduff M., Tsai W., 2005. Social network and organizations SAGE Publications. 172 pp.

Leauthaud C., Duvail S., Hamerlynck O., Paul J., Cochet H., Nyunja J., 2013. Floods and livelihoods: The impact of changing water resources on wetland agro-ecological production systems in the Tana River Delta, Kenya. Global Environmental Change 23 (1): 252–263.

Lee D. R., Edmeades S., Nys E., McDonald A., Janssen W., 2014. Developing local adaptation strategies for climate change in agriculture: A priority-setting approach with application to Latin America. Global Environmental Change 29: 78–91.

Lee J., Kim S., 2011. Exploring the Role of Social Networks in Affective Organizational Commitment: Network Centrality, Strength of Ties, and Structural Holes. The American Review of Public Administration 41 (2): 205–223.

Leonard S., Parsons M., Olawsky K., Kofod F., 2013. The role of culture and traditional knowledge in climate change adaptation: Insights from East Kimberley, Australia. Global Environmental Change 23 (3): 623–632.

Lepš J., Šmilauer P., 2003. Multivariate analysis of ecological data using CANOCO. Cambridge University Press, Cambridge, UK.

LIDEMA - Liga de Defensa del Medio Ambiente, 2010. Vulnerabilidad de los medios de vida ante el cambio climático en Bolivia. LIDEMA La Paz . 138 pp.

Macchi M., 2011. Framework for Community-Based Climate Vulnerability and Capacity Assessment in Mountain Areas. http://www.climateadapt.asia/upload/events/files/4df5851ac678bicimod-framework_for_community-based_climate_vulnerability_and_capacity_assessment_in_mountain_areas.pdf. (12.6.2012)

Manson S. M., Jordan N. R., Nelson K. C., Brummel R. F., 2014. Modeling the effect of social networks on adoption of multifunctional agriculture. Environmental Modelling and Software75: 388–401

Martin G., 2015. A conceptual framework to support adaptation of farming systems – Development and application with Forage Rummy. Agricultural Systems 132: 52–61.

Matijasevic M. J. 2014. El círculo vicioso de los efectos del cambio climático en poblaciones rurales migrantes del altiplano boliviano. Luna Azúl 38: 11–29.

McDowell J. Z., Hess J.J., 2012. Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. Global Environmental Change 22 (2): 342–352.

Mendelsohn R., Dinar A., 2009. Climate change in Agriculture: An economic analysis of global impacts, adaptation and distribution effects. The World Bank. Published by Edward Elgar Publishing limited. 246pp.

Ministerio de Desarrollo Rural y Tierras, 2014. Plan de Sector Desarrollo Agropecuario 2014-2018. Estado Plurinacional de Bolivia. La Paz 109 Pp. http://vdra.agrobolivia.gob.bo/contenidos/doc/PSDA.pdf (10.11.2015)

Morone P., Tartiu V. E., Falcone P., 2015. Assessing the potential of biowaste for bioplastics production through social network analysis. Journal of Cleaner Production 90: 43–54.

Morton J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. The National Academy of Science of the USA 104 (50): 19680–19685.

Müller R., Pacheco P., Montero J. C., 2014. The context of deforestation and forest degradation in Bolivia – Drivers, agents and institutions. Occasional paper 108. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Nelson R., Kokic P., Crimp S., Meinke H., Howden S.M., 2010. The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability. Environmental science and policy 13:1 8 – 2 7

Pacheco D., 2014. Una Mirada a la política de bosques en Bolivia; por la descolonización de las políticas. Fundación de la Cordillera, Universidad de la Cordillera, 190 pp. La Paz.

Park S., Howden M., Crimp S., 2012. Informing regional level policy development and actions for increased adaptive capacity in rural livelihoods. Environmental Science and Policy 15 (1): 23–37.

PDM-Inquisivi, 2011. Plan de Desarrollo Municipal- Municipio Inquisivi. Gobierno Municipal

PDM-Puerto Carabuco, 2011. Plan de Desarrollo Municipal – Municipio Puerto Carabuco. Gobierno Municipal.

Pearson L. J., Rohan N., Crimp S., Langridge J., 2011. Interpretive review of conceptual frameworks and research models that inform Australia's agricultural vulnerability to climate change. Environmental Modelling and Software 26 (2): 113–123.

PMOT, 2011. Ordenamiento Territotial del Municipio de Inquisivi (Distrito Centro) y alternativas para frenar el deterioro de sus suelos y mejorar la producción agrícola. Universidad mayor de San Andrés. La Paz.

PNB, 2011. Programa nacional Biocultura del Viceministerio de Medio Ambiente, biodiversidad, Cambio Climático y Desarrollo Forestal. http://www.agruco.org/agruco/noticias/25/407-programa-nacional-biocultura-del-viceministerio-de-medio-ambiente-biodiversidad-cambio-climatico-y-desarrollo-forestal- (10.10.2015)

Pretzsch J., Darr D., Uibrig H., Auch E., 2014. Forest and Rural Development. Springer. Heidelberg.

PROIMPA, 2008. Informe de Bolivia NUS-IFAD II: "Fortalecimiento de las oportunidades de ingreso y la seguridad nutricional de los pobres rurales, a través del uso y mercadeo de especies olvidadas y subutilizadas". International fund for agricultural development. – IFAD- Bioversity International. 307 pp. La Paz.

PROIMPA, 2009. Informe de Bolivia NUS-IFAD II: "Fortalecimiento de las oportunidades de ingreso y la seguridad nutricional de los pobres rurales, a través del uso y mercadeo de especies olvidadas y subutilizadas". International fund for agricultural development. – IFAD- Bioversity International, 203 p. La Paz .

Quispe M., Augster S., 2011. Experiencias del Proyecto "Reducción de riesgos climáticos en la producción agrícola a través de una construcción de conocimientos compartida".In: FAO 2011. Taller internacional, Experiencias exitosas de gestión de riesgos de desastres del sector agropecuario para la adaptación al cambio climático. Impresiones Punto de Encuentro 344 p. La Paz.

Ramirez A., 2013. The Influence of Social Networks on Agricultural Technology Adoption. Procedia - Social and Behavioral Sciences 79: 101–116.

Reed M.S., Podesta G., Fazey I., Geeson N., Hessel R., Hubacek K., Letson D., Nainggolan D., Prell C., Rickenbach M.G., Ritsema C., Schwilch G., Stringer L.C., Thomas A.D., 2013. Combining analytical frameworks to assess livelihood vulnerability to climate change and analyze adaptation options. Ecological Economics 94 (2013): 66–77.

Ricciardi V., 2015. Social seed networks: Identifying central farmers for equitable seed access. Agricultural Systems 139: 110–121.

Rico García-Amado L., Ruiz Pérez M., Iniesta-Arandia I., Dahringer G., Reyes F., Barrasa S., 2012. Building ties: social capital network analysis of a forest community in a biosphere reserve in Chiapas, Mexico. Ecology and Society 17 (3): 3–15.

Righi A., 2013. Measuring Social Capital: Official Statistics Initiatives in Italy. Procedia - Social and Behavioral Sciences 72: 4–22.

Rist S., Dahdouh-Guebas F., 2006. Ethnosciences—A step towards the integration of scientific and indigenous forms of knowledge in the management of natural resources for the future. Environ Dev Sustain 8 (4): 467–493.

Rodima-Taylor D., 2012. Social innovation and climate adaptation: Local collective action in diversifying Tanzania. Applied Geography 33: 128–134.

Baumgartner R., Högger R., Rist S., 2011. Hacia estrategias de vida sostenibles Culturas, recursos y cambios en India y Bolivia. AGRUCO / NCCR North-South / NADEL / CDE / PLURAL. First Ed. Plural, 194 pp. Cochabamba.

Ruiz-Mallén I., Corbera E., 2013. Community-Based Conservation and Traditional Ecological Knowledge: Implications for Social-Ecological Resilience. Ecology and Society 18 (4): 12–31.

Sankar C., Asokan K., Satheesh Kumar K., 2015. Exploratory social network analysis of affiliation networks of Indian listed companies. Social Networks 43: 113–120.

SENAMHI – Servicio Nacional de Meteorología e Hidráulica Bolivia, 2012 http://www.senamhi.gob.bo/ (20.10.2013)

Skjeflo S., 2013. Measuring household vulnerability to climate change: Why markets matter. Global Environmental Change 23 (6): 1694–1701.

Soltani A., Angelsen A., Eid T., Naieni M.S.N., Shamekhi T., 2012. Poverty, sustainability, and household livelihood strategies in Zagros, Iran. Ecological Economics 79: 60–70.

Tang Q., Bennett S.J., Xu Y., Li Y., 2013. Agricultural practices and sustainable livelihoods: Rural transformation within the Loess Plateau, China. Applied Geography 41: 15–23.

Ticehurst S., Sagrario U., Best S., 2009. Bolivia: Climate change, poverty and adaptation. Bolivia: OXFAM International. http://www.oxfam.org/sites/www.oxfam.org/files/bolivia-climate-change-adaptation-0911.pdf (20.045.2014)

Toledo V.M., 2012. Ethnoecology: A conceptual framework for study of indigenous Knowledge of nature. Ethnobiology and Biocultural Diversity. Stepp (Ed.), International Society of Ethnobiology.12: 511-522 pp.

Torrico J.C., Mallea M.I., 2012. Pobreza e inseguridad alimentaria en zonas rurales de montaña: Caso de Bolivia. Revista virtual REDESMA. 6 (1). http://www.revistasbolivianas.org.bo/pdf/rvr/v6n1/v6n1_a04.pdf (15.06.2013)

Turner N.J., 2009. "It's so different today": Climate change and indigenous lifeways in British Columbia, Canada. Global Environmental Change 19 (2): 180–190.

Valdimir M., Chirveches M., 2010 Gestion sustentable de la diversidad biocultural. Estrategias y metodologías de incidencia política para el vivir bien. AGRUCO-BioAndes / Plural editores. Cochabamba.

Valdivia A. S., Jimenez E., Cusicanqui J., 2013. Cambio Climático y Adaptación en el Altiplano Boliviano. 17 – 46 pp. In: Jiménez 2013. En Cambio climático y adaptación en el altiplano boliviano. CIDES-UMSA. Plural Editores.

van den Berg M., 2010. Household income strategies and natural disasters: Dynamic livelihoods in rural Nicaragua. Ecological Economics 69 (3): 592–602.

Vedeld P., Angelsen A., Bojö J., Sjaastad E., Kobugabe Berg G., 2007. Forest environmental incomes and the rural poor. Forest Policy and Economics 9 (7):869–879.

Viceministerio de Medio Ambiente, Biodiversidad y Cambio Climático (VMMABCC). Programa Nacional de Cambios Climáticos. 2009. Estrategia Nacional Bosque y Cambio Climático. Ministerio de Medio Ambiente y Agua – Estado Plurinacional de Bolivia, 35 p.

Vidaurre M., Lindner A., Pretzsch J., 2013. Assessing Adaptation - Climate Change and Indigenous Livelihood in the Andes of Bolivia. Journal of Agriculture and Rural Development in the Tropics and Subtropics 114 (2): 109–122.

Wang J., Brown D.G., Agrawal A., 2013. Climate Adaptation, Local Institutions, and Rural Livelihoods: A Comparative Study of Herder Communities in Mongolia and Inner Mongolia, China. In: Global Adger W. N., Vincent K., 2005. Uncertainty in adaptive capacity. Comptes Rendus Geoscience 337 (4): 399–410.

Wiggins S., 2009. CEDRA: Climate change and Environmental Degradation Risk and Adaptation assessment. Tearfund. http://www.preventionweb.net/files/11964_CEDRAClimatechangeandEnvironmentalD.pdf (13.08.2013)

Williams H., McMurray T. P., James R., Kurz T., Lambert F., 2015. Network analysis reveals open forums and echo chambers in social media discussions of climate change. Global Environmental Change 32: 126–138.

Williamson T., Hesseln H., Johnston M., 2012. Adaptive capacity deficits and adaptive capacity of economic systems in climate change vulnerability assessment. Forest Policy and Economics 15: 160–166.

Yin R., 2009. Case Study Research – Design and Methods. Fourth Edition. Applied social research methods series, Volume 5. SAGE publications. 219 pp. United States, United Kindom, India, Singapore.

Zenteno Mario, Zuidema Pieter A., Jong Wil de, Boot René G.A., 2013. Livelihood strategies and forest dependence: New insights from Bolivian forest communities. Forest Policy and Economics 26: 12–21.

Ziche J., Rist S., 2001. La cara interna y anímico-espiritual del “desarrollo”- La comprencion del desarrollo que tienen los campesinos Aymaras de Bolivia. Land-Berichte 7: 122-132.

11. APPENDIX

Appendix 1: Key informant interview

The key informant interviewed have been selected from municipality staff, a social organization that works with the community: governmental and non-governmental organizations, local syndicates, associations, unions and local enterprises integrated by members from the communities selected.

1. General information about the social organization (list of open questions)

- What are the objectives, mission of the social organization?
- What is the relationship between the social organization and local households in the community?
- What are the observed and predicted impacts of socio-economic conflicts and climate change for the community?
- What livelihood groups or economic sectors are most vulnerable to socio-economic and climate change?
- Do local plans or policies support climate-resilient livelihoods?
- What are the most important climate-related hazards the community? and socio-economic related?
- What institutions (governmental and non-governmental) are involved to support adaptation to social and climatic changes?
- Are resources allocated for implementation of adaptation-related policies? What is the budget? Where are the resources coming from?
- What are the existing capacity and resource needs and/or gaps?
- What new capacities may be needed to address changing circumstances? What social groups within the community are most vulnerable to climate change?
- Do women and other marginalized groups have a voice in local planning processes?
- What are the other factors constraining the adaptive capacity of the most vulnerable groups? Do vulnerable communities and groups have any influence over these factors?

2. Assessment of social networks

2.1 Identification of socio-economic conflicts at the community level that affect the well-being of the households.

Frequent problems	Resources affected	Solutions	Outcomes	Staff in charge
1				
2				
3				
… *n*				

2.2 Identification of actors in the network under socio-economic conflicts

Name all actors that support socio-economic	Relationship	Strategy	Frequency
1			
2			
3			
…*n*			

2.3 Identification of extreme weather events at the community level that affect the well-being of the households.

Frequent problems	Resources affected	Solutions	Outcomes	Staff in charge
1				
2				
3				
… *n*				

2.4 Identification of actors in the network under extreme weather events

Name all actors that support socio-economic	Relationship	Strategy	Frequency
1			
2			
3			
…*n*			

Appendix 2: Household interview

1. Household information

Name	Age	Gender	Education	Place of living	Principal activity	Language	Health	Chronic disease	Health insurance
Household head									
Sponsor									
Children									
Others									

2. Shelter

Shelter	Quantity	cost	Access to Services	Frequency	cost
Private land			Drinking water		
Private house			Distance to health center		
Number of rooms			Public transportation		
Thatched roof, calamine			Electricity		
Cooking: gas, firewood, others			Climatic information		
Distance to the road			Private transportation		
Latrine / bathroom / shower			Agricultural insurance		
Wall of brick / adobe			Private savings/debts		

3. Livestock

Livestock	Quantity	Price	Vaccine cost	Veterinary cost	Food cost	Related problems
1						
2						
3						
n…						

4. Agriculture

Plot	Size	Private/rented	Location	Irrigation	Plow	Fertilizer	Pesticide	Current crop	Problems
1									
2									
3									
n…									

Time invest in the last year/ plot

5. Agrobiodiversity

Crop	Varieties	Seed	Quantity last year harvesting	Current harvesting	Market prices	Transformed products	Destination: consumption /market
1							
2							
n…							

6. Market

Product (livestock/crops)	Amount sold	Price sold	Distance to the market	Related expenses
1				
2				
3				
n…				

7. Economic activities : all economic activities developed during the last year by household members

Economic activity	Family member	Investment ($/time)	Cash income($/time)	Time invested (day, week, month)	Season
1					
2					
3					
n…					

The activities included: bonds, remittance, a collection of natural resources, eucalyptus plantation, tourism, honey production, wage labor, and others.

8. Traditional ecological knowledge

Type of knowledge	Description	When to use this TEK	Frequency of use (0-5)
Rituality			
Identification with Aymara culture			
Knowledge acquired from parents			
Transfer of knowledge to new generation			
Weather forecasting indicators			
Medicinal plants			
Food storage techniques			
Product exchanges with other households			
Product exchanges with other communities			
ayni, minka practices			

9. Socio-economic problems identification

Description of the situation	Resource affected	Taking actions to solve the problem	How helps to solve the problem

10. Identification of social networks when a socio-economic conflict affects the household

Name people with whom you relate, including local and municipal authorities and community members	relationship	Implemented strategy	Frequency of interaction
1			
2			
3			
n…			

11. Identification of extreme weather event

EWE description	Impact	Affected livelihood resources	Intensity (1-5)	Season	Actions taking
1					
2					
3					
n…					

12. Identification of social networks when extreme weather events affect the household

Name people with whom you relate, including local and municipal authorities and community members	relationship	Implemented strategy	Frequency of interaction
1			
2			
3			
n…			

Declaration of independent work

Note on the commencement of the doctoral procedure

1. I hereby assure that I have produced the present work without inadmissible help from third parties and without aids other than those stand; ideas taken directly or indirectly from external sources are identified as such.
2. When selecting and evaluating the material and also when producing the manuscript, I have received support from the following persons: Prof. Dr. Jürgen Pretzsch, Prof. Dr. Elizabeth Jiménez Zamora, Prof. Dr. Perdita Pohle, Prof. Dr. Gerald Kapp and Dr. André Lindner.
3. No further persons were involve in the intellectual production of the present work. In particular, I have not received help from a commercial doctoral adviser. No third parties have received monetary benefits from me, either directly or indirectly, for work relating to the content of the presented dissertation.
4. The work has not previously been presented in the same or similar format to another examination body in Germany or abroad, nor has it is a cumulative dissertation – been published.
5. If this concerns a cumulative dissertation in accordance with Section 10 Para. 2, 1 assure compliance with the conditions laid down therein.
6. I confirm that I acknowledge the doctoral regulations of the faculty of Environmental science of the Technische Universität Dresden.

Tharandt, 13.05.2016

Marolyn Vidaurre de Mulczyk M.Sc.

Doctoral student